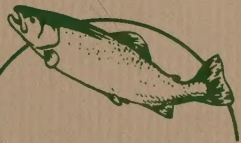
# SURFACE CURRENTS OF LAKE MICHIGAN 1931 AND 1932



SPECIAL SCIENTIFIC REPORT–FISHERIES No. 413

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE

UNITED STATES DEPARTMENT OF THE INTERIOR, Stewart L. Udall, *Secretary*
FISH AND WILDLIFE SERVICE, Clarence F. Pautzke, *Commissioner*
BUREAU OF COMMERCIAL FISHERIES, Donald L. McKernan, *Director*

# SURFACE CURRENTS OF LAKE MICHIGAN, 1931 AND 1932

by

John Van Oosten

United States Fish and Wildlife Service
Special Scientific Report--Fisheries No. 413

Washington, D. C.
1963

# CONTENTS


| | Page |
|---|---|
| Introduction | 1 |
| History of Lake Michigan current studies | 1 |
| Materials and methods | 3 |
| Releases and recoveries by transect and course | 5 |
| Chicago to St. Joseph | 5 |
| St. Joseph to Grand Haven to nets | 11 |
| Ludington to nets and Manistee to Two Rivers | 13 |
| Sheboygan to Sheboygan Reef to Racine | 15 |
| Waukegan to St. Joseph | 17 |
| Racine to Grand Haven | 19 |
| Frankfort to Two Rivers to nets | 21 |
| Frankfort to Kewaunee | 23 |
| Kewaunee to Port Washington | 25 |
| Escanaba to Menominee | 25 |
| Menominee to nets and return | 28 |
| Two Rivers to Frankfort | 31 |
| Frankfort to Charlevoix | 31 |
| Charlevoix to Manistique | 31 |
| Manistique to Escanaba | 31 |
| Manistique to Manistee | 31 |
| Manistee to Grand Haven | 31 |
| Grand Haven to Sheboygan | 33 |
| Sheboygan to Sturgeon Bay | 33 |
| Charlevoix to Guiken's Reef | 34 |
| Gull Island to Manistique | 34 |
| Charlevoix to Dahlia Shoal and northwest of Charlevoix | 36 |
| General characteristics | 36 |
| Summary | 50 |
| Literature cited | 50 |

# SURFACE CURRENTS OF LAKE MICHIGAN, 1931 AND 1932

by

John Van Oosten
Fishery Research Biologist
Bureau of Commercial Fisheries
U. S. Fish and Wildlife Service
Ann Arbor, Michigan

## ABSTRACT

Seven hundred forty-five bottles containing post cards for recording of information were released at stations in Lake Michigan; 283 were released June 17 to August 17, 1931, south of a line from Frankfort, Michigan, to Algoma, Wisconsin, and 462 during May 9 to August 25, 1932, both south and north of that line.

One hundred eighty-six bottles or 65.7 percent of those released in 1931, 331 bottles or 71.6 percent of 1932 releases, and 517 bottles or 69.4 percent of releases in the 2 years were recovered.

Recoveries of bottles from both years indicated that the surface currents were somewhat variable, but their general direction was from west to east and predominately northeast in 1931 and northeast and southeast in 1932.

## INTRODUCTION

Currents have been observed in the Great Lakes by many people. These water movements affect navigation, kind of water at intakes, temperatures, plankton, fishes, beaches, and recreation. Currents of Lake Michigan have been discussed in numerous papers. The present study is based on the recovery of drift bottles that were dropped from the research vessel *Fulmar*, operated by the U. S. Bureau of Fisheries in 1931 and 1932. I am greatly indebted to the members of the scientific staff of this vessel who prepared and deposited the bottles. Asa T. Wright drafted all of the figures.

## HISTORY OF LAKE MICHIGAN CURRENT STUDIES

Harrington (1895) reported, on the basis of recoveries of bottles released in 1892, 1893, and 1894 by the U.S. Weather Bureau, that the main current of Lake Michigan passed southward off the west shore, curved eastward along Illinois and Indiana, and moved northward along the east shore, although certain cross currents and eddies occurred in the center of the lake. Russell (1895) discussed the friction of winds on water movements of the Great Lakes and showed the Weather Bureau's map of Great Lakes currents. Ward (1896) described the Bureau's chart of Lake Michigan.

Judson (1909) listed nine factors that may influence the currents of Lake Michigan but concluded that the all-important one was the wind. The winds and barometric pressure produce currents that travel in any direction; even in the Straits of Mackinaw the current may flow either into Lake Huron or Lake Michigan and vary greatly in velocity. (This reverse flow in the Straits of Mackinaw was observed by explorers as early as 1673.) According to Judson, surface currents travel a maximum of about 5 percent of the wind speed up to 3 miles per hour and extend to a depth of 30 to 40 feet.

Barnard and Brewster (1909a and 1909b) reported that local shore currents reach a maximum distance of 5 miles from Michigan City and at times beyond 10 miles from certain areas of the Indiana coast. These currents flow in many directions according to the prevailing winds. McLaughlin (1912) mentioned winds and inshore currents but stated that the prevailing current of Lake Michigan sweeps southward into Grand Traverse Bay and moves from west and east and then northward toward the open lake. At times the currents reverse from east to west.

Townsend (1916) derived his paper from a voluminous document of the House of Representatives (No. 762, 63d. Congress, 2d. Session) that included Great Lakes data on winds, water levels, temperatures, and currents. He pointed out that curvilinear surface currents illustrated by Harrington's map of Lake Michigan were absurd because the 2 points of a drift bottle's course could only represent a straight line. No permanently defined currents are developed, he contended, because as a rule they follow the direction of surface winds and perhaps are affected by barometric pressures. The currents may flow opposite the wind when its intensity is low. Floats deposited close to Wisconsin were recovered on that shore, north or south of the release point, whereas the floats released farther out in the lake were driven by prevailing westerly summer winds across to Michigan. Eddies may develop but only in deep bays or between extended points along the shore--not along an unbroken shore.

Shelford (1918) described the conditions in Lake Michigan and among them referred to the wave action that varied from depths up to 5 feet, the limit of sand-moving waves, to 26 feet; the limit of wave action is 82 feet.

Horton and Grunsky (1927) also reported that strong wind action and barometric pressure increase the normal current in the Straits of Mackinaw and at times reverse it from Lake Huron into Lake Michigan.

Crohurst and Veldee (1927) stated that no constant or clearly defined water currents exist in the Calumet region of Illinois and Indiana. The movements vary continuously with wind direction and velocity and should be termed "wind drifts" rather than true currents. Their observations with floats were not useful.

It is unfortunate that our 1931 and 1932 data on the surface currents of Lake Michigan were not recorded years ago. However, Deason (1932) published a preliminary report of our 1931 program including records of five of our interesting recoveries of drift bottles. A short notice of the drift-bottle study of 1931 appeared in the U.S. Fisheries Service Bulletin, No. 202, March 1, 1932.

The limnological surveys of Lake Michigan by the Bureau of Commercial Fisheries in 1954-56 and 1960 were briefly reported in the Commercial Fisheries Reveiw. Several reports showed the pattern and direction of currents as indicated by drift cards.

Smith (1956) described the release of 4,000 drift bottles in the northern half of Lake Michigan in 1955. Nearly 60 percent of them were returned by the end of the year. An experiment indicated that the shortening of wire between the drag and the bottle from 3 feet to 1 foot and the addition of a movable brass ring at the neck of the bottle reduced the loss of drags. In his 1957 paper Smith reported a total of 6,300 drift bottles released in the southern half of Lake Michigan in 1954 and in the northern half in 1955.

Lauff (1957) released no drift bottles during his 2-day survey of Grand Traverse Bay on

July 30-31, 1954, but recorded the Lake Michigan bottles that were recovered in the bay, 6 reported in 1892 by Harrington (1894) and 11 in 1955 by the Great Lakes Research Institute. These bottles indicated that the main current flowed into the West Arm and a small portion deflected into the East Arm.

Ayers et al. (1958) reported the release of 1,297 drift bottles in Lake Michigan during four synoptic cruises (15 round trips) on June 28 and 29 and August 9 and 10, 1955; 239 bottles or 18.4 percent were recovered. Eighteen percent of the recovered bottles were found in the southern half and 82 percent in the northern half of the lake. Nearly all bottles recovered from releases in June had traveled northeastward but most of those of August floated southeastward. Fifty-seven percent of the retrieved bottles were from the eastern area of the lake, while 17, 16, and 10 percent, respectively, were recovered from the western, central, and northern areas. Twenty-one bottles were discovered in Lake Huron.

Johnson (1960) described surface currents in Lake Michigan during 1954 and 1955. From July 9 through September 15, 1954, 1,080 drift bottles, 1,080 drift envelopes, and 100 plastic tubes were released along two transects (six trips) in the southern area and one transect (one trip) in the central region. Returns of these drift units amounted to 587 bottles (54.4 percent), 77 envelopes (7.1 percent), and 18 tubes (18.0 percent). In general, the 1954 drift was from west to east. Recoveries toward the north and south were about equal.

During April 26 to November 8, 1955, 2,000 drift bottles with drags and 2,000 bottles with sand ballast were released along two transects (six trips) in the central region, two transects (nine trips) in the northern area, and one cruise between Manitowoc and Sturgeon Bay, Wisconsin. Returns included 1,128 or 56.4 percent of the bottles with drags and 1,060 or 53.0 percent of those with ballast. The general drift of the 1955 bottles was from west to east. Bottles released in the eastern areas moved mainly to the north, but those dropped to the west showed no prevailing pattern.

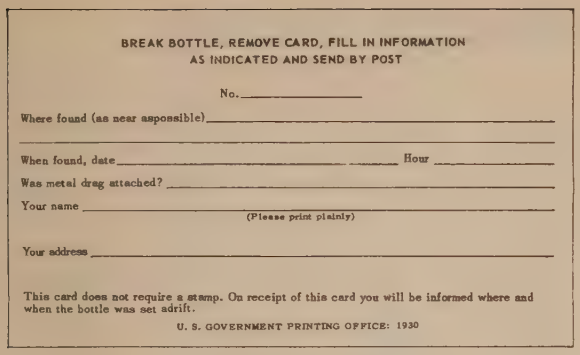
## MATERIALS AND METHODS

Our drift bottles released in 1931 and 1932 had a capacity of 13.9 ounces and were made of heavy glass with the initials U.S.B.F. blown in the side (fig. 1). A metal drag suspended by 3 feet of wire from the bottom of the wired bottle could rotate within a restricted arc. The drag, composed of 22-gauge galvanized iron, was bent in such a manner that the bottles resisted direct effects of wind and thus gave a true indication of surface currents. Each bottle contained a numbered post card (fig. 2) that requested the following information: locality, date, and hour of recovery; whether or not a metal drag was attached; name and address of the finder. The cards were addressed to the U.S. Bureau of Fisheries, Washington, D. C., and included a notice that the finder would be informed where and when the bottle was set adrift. The bottles also contained a strip of red muslin about 1-inch wide, part of which extended outside and floated along the surface, to attract attention. The corks and muslin that stoppered the bottles were heavily waxed.

Series of bottles (table 1; fig. 3) were released across Lake Michigan between the following ports: Chicago, Illinois, and St. Joseph, Michigan; Waukegan, Illinois, and St. Joseph, Michigan; Racine, Wisconsin, and Grand Haven, Michigan; Grand Haven, Michigan, and Sheboygan, Wisconsin; Manistee, Michigan, and Two Rivers, Wisconsin; Frankfort, Michigan, and Two Rivers, Wisconsin; Frankfort, Michigan, and Kewaunee, Wisconsin; and Manistique, Michigan, and Manistee, Michigan. In addition, bottles were released along the courses between ports of the same coast, between ports and net stations, and at various locations where gill nets were set.

In 1931, 293 bottles were released from June 17 to August 17 in the open lake south of a line from Frankfort, Michigan, to Algoma, Wisconsin (table 1). One hundred eighty-six bottles or 65.7 percent were recovered. The percentages varied from 25.0 to 100.0. From May 9 to August 25, 1932, 462 bottles were deposited south and north of the above-defined line and in Green Bay. The recoveries totaled 331 bottles or 71.6 percent. The percentages

Figure 1.--Drift bottle with a metal drag, was deposited from the research vessel *Fulmar*.



BREAK BOTTLE, REMOVE CARD, FILL IN INFORMATION
AS INDICATED AND SEND BY POST

No._____

Where found (as near aspossible)_____

When found, date_____ Hour _____

Was metal drag attached? _____

Your name _____
(Please print plainly)

Your address _____

This card does not require a stamp. On receipt of this card you will be informed where and when the bottle was set adrift.

U. S. GOVERNMENT PRINTING OFFICE: 1930

Figure 2.--Post card, 3¼ by 5½ inches, included in bottle.

ranged from 46.2 to 95.1. A grand total of 745 bottles were deposited, and 517 bottles or 69.4 percent were recovered. Most of the release stations were approximately 2 miles apart although a distance of about 1 mile was employed on three dates.

Unknown numbers of bottles landed many weeks or months before their recovery; many of them no doubt remained at about the same location, but some could have been moved by winds, waves, or ice. However, the largest monthly numbers and percentages (table 2) followed the month when the bottles were released except August, when the major recoveries occurred in the month of release. The majority of the bottles had been recovered by the end of August 1931 and of July 1932. For the combined years, the greatest number of recoveries was in July. As the season progressed in both 1931 and 1932 the monthly figures decreased and reached zero as early as September (May release of 1932).

The numbers and percentages of the bottles recovered were recorded also according to the number of days (table 3). During the first 9 days 6 bottles (2.1 percent) were recovered in 1931 and 46 bottles (10.0 percent) in 1932--a total of 52 bottles (7.0 percent) for both years. From the 10th until the 50th day the percentages for the 10-day period varied from 9.9 to 13.4 in 1931, 8.2 to 10.8 in 1932, and 9.7 to 11.8 in the 2 years combined. They then decreased until the 80th day, and thereafter averaged below 2 percent (including those beyond 129 days). The highest percentages were between 30 and 39 days.

Many recovered bottles had lost their drags. In 1931, 120 (64.5 percent) and in 1932, 133 (40.2 percent) of the bottles had no drags, a grand total of 253 (48.9 percent)--see table 3. The percentages of the lost drags of 1931-32 bottles increased generally to a maximum of 80.0 during the period of 90-99 days but subsequently averaged about 59 percent. Bottles that held their drags amounted to 58 (31.2 percent) in 1931, 169 (51.0 percent) in 1932, and 227 (43.9 percent) in both years. Thirty-seven (7.2 percent) of the cards gave no report on the drag.

Only 16 drift bottles, at least 10 of which had lost their drags, were found more than 1 year after release (table 3)--13 in 1932-36, 2 in 1938, and 1 in 1942. Only two bottles were recovered beyond Lake Michigan. One released June 22, 1931, 43.5 miles from Frankfort, Michigan, was found April 8, 1935, at St. Martins Point, St. Martins Bay, Lake Huron. Another, released June 24, 1932, 6.7 miles from Kewaunee, Wisconsin, was recovered June 6, 1942, near Jefferson Beach, Lake St. Clair.

## RELEASES AND RECOVERIES BY TRANSECT AND COURSE

The following sections include 19 graphs of recoveries showing the directions followed by recovered bottles. Tables 4-24 list the stations of release and recovery of drift bottles, number of days, minimum miles traveled, and records of drags.

### Chicago to St. Joseph

On June 17, 1931, 27 bottles (table 4) were released along the transect (fig. 4) and 23 (85 percent) were recovered in 17-76 days, an average of 43.7. Eight (40 percent) of the 20 bottles held their drags. The bottles had covered minimum distances from 9-144 miles an average of 61.5. Sixteen bottles, including six on the western part of the transect, scattered widely on the east coast from 8 miles south of St. Joseph to 7 miles south of Manistee.

TABLE 1.--Number of drift bottles released along various transects or courses (and station numbers) by the research vessel *Fulmar* in Lake Michigan, 1931 and 1932, and the numbers and percentages recovered

| Date | Transect or course | Stations [1] | Number of bottles | | Percentages recovered |
|---|---|---|---|---|---|
| | | | Released | Recovered | |
| *1931* | | | | | |
| June 17 | Chicago, Ill. -St. Joseph, Mich. | 1- 27 | 27 | 23 | 85.2 |
| June 18 | St. Joseph, Mich. -Grand Haven, Mich. | 28- 40 | 13 | 12 | 92.3 |
| June 22 | Grand Haven, Mich. -Ludington, Mich. | 41- 44 | 4 | 4 | 100.0 |
| June 23 | Ludington, Mich. -Manistee, Mich. | 45- 48 | 4 | 1 | 25.0 |
| June 24 | Manistee, Mich. -Two Rivers, Wis. | 49- 75 | 27 | 24 | 88.9 |
| June 26 | Sheboygan, Wis. -Sheboygan Reef | 76- 82 | 7 | 4 | 57.1 |
| June 27 | Sheboygan, Wis. -Sheboygan Reef | 83- 91 | 9 | 5 | 55.6 |
| June 27 | Sheboygan Reef-Racine, Wis. | 92-117 | 26 | 20 | 76.9 |
| June 30 | Waukegan, Ill. -St. Joseph, Mich. | 118-147 | 30 | 24 | 80.0 |
| July 17 | Racine, Wis. -Grand Haven, Mich. | 148-183 | 36 | 27 | 75.0 |
| July 22 | Frankfort, Mich. -Two Rivers, Wis. | 184-217 | 34 | 18 | 52.9 |
| July 23 | Two Rivers, Wis. -Nets | 218-221 | 4 | 2 | 50.0 |
| July 30 | Frankfort, Mich. -Nets-Kewaunee, Wis. | 222-249 | 28 | 7 | 25.0 |
| Aug. 12 | Kewaunee, Wis. -Nets-Port Washington, Wis. | 250-282 | 33 | 14 | 42.4 |
| Aug. 17 | Grand Haven, Mich. -Nets | 283 | 1 | 1 | 100.0 |
| Total or average | | 283 | 283 | 186 | 65.7 |
| *1932* | | | | | |
| May 9 | Escanaba, Mich. -Menominee, Mich. | 284-308 | 25 | 16 | 64.0 |
| May 17 | Menominee, Mich. -Nets and return | 309-337 | 29 | 19 | 65.5 |
| June 2 | Two Rivers, Wis. -Frankfort, Mich. | 338-413 | 76 | 57 | 75.0 |
| June 3 | Frankfort, Mich. -Charlevoix, Mich. | 414-483 | 70 | 51 | 72.8 |
| June 6 | Charlevoix, Mich. -Manistique, Mich. | 484-537 | 54 | 35 | 64.8 |
| June 7 | Manistique, Mich. -Escanaba, Mich. | 538-559 | 22 | 16 | 72.7 |
| June 20 | Manistique, Mich. -Manistee, Mich. | 561-587 | 27 | 20 | 74.1 |
| June 21 | Manistee, Mich. -Grand Haven, Mich. | 588-628 | 41 | 39 | 95.1 |
| June 23 | Grand Haven, Mich. -Sheboygan, Wis. | 629-666 | 38 | 27 | 71.0 |
| June 24 | Sheboygan, Wis. -Sturgeon Bay, Wis. | 667-699 | 33 | 25 | 75.8 |
| Aug. 9 | Charlevoix, Mich. -Guiken's Reef | 700-714 | 15 | 8 | 53.3 |
| Aug. 20 | Gull Island-Manistique, Mich. | 715-726 | 12 | 7 | 58.3 |
| Aug. 23 | Charlevoix, Mich. -Dahlia Shoal | 727-739 | 13 | 6 | 46.2 |
| Aug. 25 | Charlevoix, Mich. (12 3/8 miles NW 1/8 W) | 740-746 | 7 | 5 | 71.4 |
| Total or average | | 462 | 462 | 331 | 71.6 |
| Grand total or average | | 745 | 745 | 517 | 69.4 |

[1] No. 560 was not used.

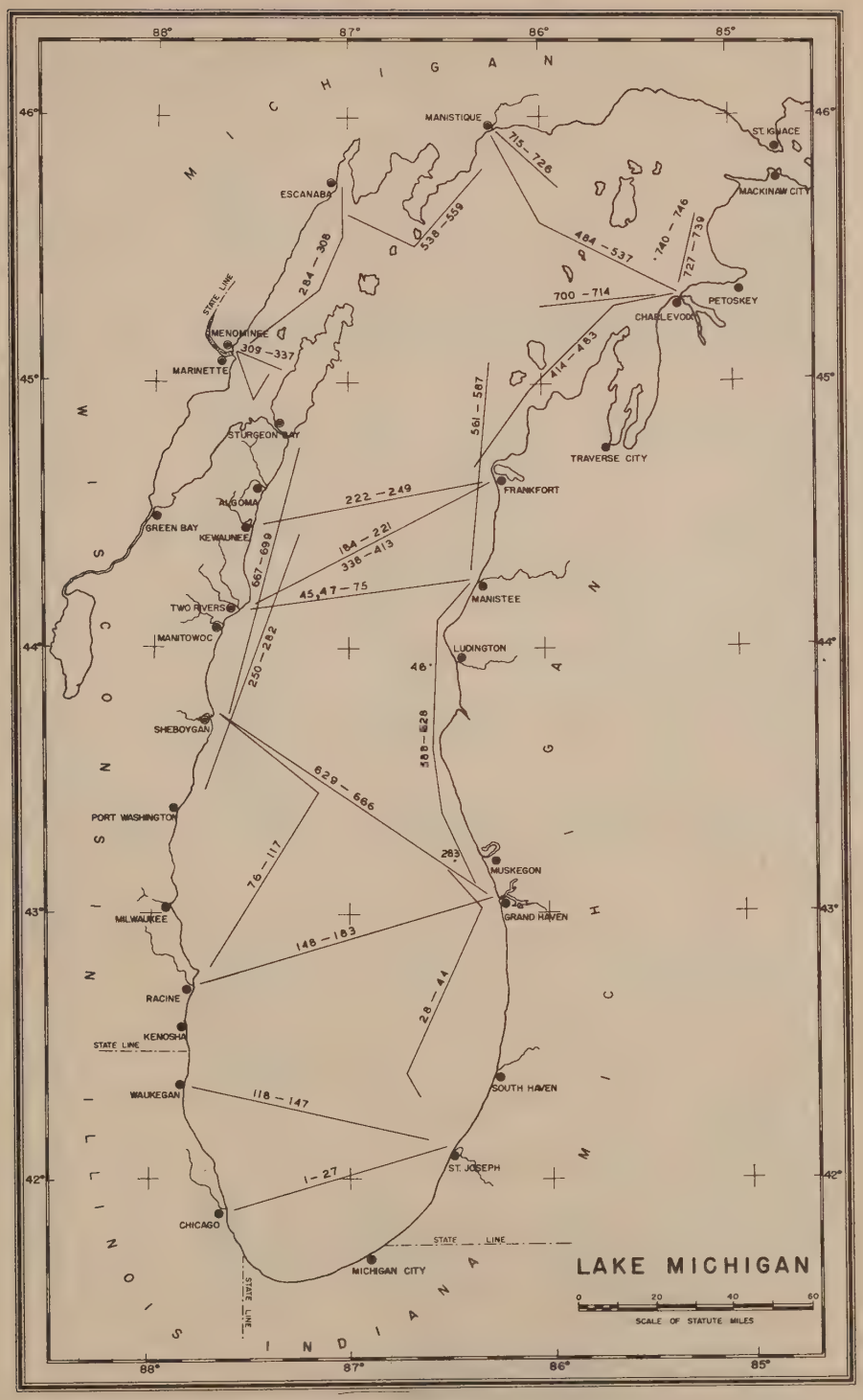



Figure 3.--Bottles were released along the transects and along the coasts of Lake Michigan.

TABLE 2. --Numbers of bottles recovered and their percentages of the bottles released in Lake Michigan 1931-32
[Numbers of released bottles in parentheses below dates of releases]

| Released | Item | Numbers of recoveries and percentages of bottles released | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | May | June | July | August | September | October | November | December | Beyond December | Totals |
| *1931* | | | | | | | | | | | |
| June 17-30 | Number | ... | 1 | 67 | 43 | 4 | 1 | 0 | 0 | 1 | 117 |
| (147) | Percentage | ... | 0.7 | 45.6 | 29.2 | 2.7 | 0.7 | 0.0 | 0.0 | 0.7 | 79.6 |
| July 17-30 | Number | ... | ... | 3 | 32 | 7 | 7 | 1 | 0 | 4 | 54 |
| (102) | Percentage | ... | ... | 2.9 | 31.4 | 6.9 | 6.9 | 1.0 | 0.0 | 3.9 | 52.9 |
| Aug. 12-17 | Number | ... | ... | ... | 13 | 1 | 0 | 0 | 0 | 1 | 15 |
| (34) | Percentage | ... | ... | ... | 38.2 | 2.9 | 0.0 | 0.0 | 0.0 | 2.9 | 44.1 |
| All dates | Number | ... | 1 | 70 | 88 | 12 | 8 | 1 | 0 | 6 | 186 |
| (283) | Percentage | ... | 0.4 | 24.7 | 31.1 | 4.2 | 2.8 | 0.4 | 0.0 | 2.1 | 65.7 |
| | Cumulative | ... | 0.4 | 25.1 | 56.2 | 60.4 | 63.2 | 63.6 | 63.6 | 65.7 | 65.7 |
| *1932* | | | | | | | | | | | |
| May 9-17 | Number | 2 | 19 | 8 | 1 | 0 | 0 | 0 | 1 | 4 | 35 |
| (54) | Percentage | 3.7 | 35.2 | 14.8 | 1.8 | 0.0 | 0.0 | 0.0 | 1.8 | 7.4 | 64.8 |
| June 2-24 | Number | ... | 59 | 129 | 50 | 13 | 4 | 3 | 0 | 12 | 270 |
| (361) | Percentage | ... | 16.3 | 35.7 | 13.8 | 3.6 | 1.1 | 0.8 | 0.0 | 3.3 | 74.8 |
| Aug. 9-25 | Number | ... | ... | ... | 8 | 7 | 1 | 1 | 0 | 9 | 26 |
| (47) | Percentage | ... | ... | ... | 17.0 | 14.9 | 2.1 | 2.1 | 0.0 | 19.1 | 55.3 |
| All dates | Number | 2 | 78 | 137 | 59 | 20 | 5 | 4 | 1 | 25 | 331 |
| (462) | Percentage | 0.4 | 16.9 | 29.6 | 12.8 | 4.3 | 1.1 | 0.9 | 0.2 | 5.4 | 71.6 |
| | Cumulative | 0.4 | 17.3 | 46.9 | 59.7 | 64.0 | 65.1 | 66.0 | 66.2 | 71.6 | 71.6 |
| Both years | Number | 2 | 79 | 207 | 147 | 32 | 13 | 5 | 1 | 31 | 517 |
| (745) | Percentage | 0.3 | 10.6 | 27.8 | 19.7 | 4.3 | 1.7 | 0.7 | 0.1 | 4.2 | 69.4 |
| | Cumulative | 0.3 | 10.9 | 38.7 | 58.4 | 62.7 | 64.4 | 65.1 | 65.2 | 69.4 | 69.4 |

TABLE 3.--Numbers and percentages of bottles from the 1931 and 1932 releases recovered, and the lost and nonreported drags according to days between release and recovery

| Numbers of days from release to recovery | Bottles recovered from 1931 releases | | Bottles recovered from 1932 releases | | Bottles recovered from 1931-32 releases | | Bottles from 1931-32 releases that had lost drags | | Number of bottles from 1931-32 releases without data on drags |
|---|---|---|---|---|---|---|---|---|---|
| | Number | Percentage | Number | Percentage | Number | Percentage | Number | Percentage | |
| 10 | 6 | 2.1 | 46 | 10.0 | 52 | 7.0 | 8 | 15.4 | 1 |
| 10- 19 | 29 | 10.2 | 43 | 9.3 | 72 | 9.7 | 23 | 31.9 | 4 |
| 20- 29 | 36 | 12.7 | 38 | 8.2 | 74 | 9.9 | 41 | 55.4 | 3 |
| 30- 39 | 38 | 13.4 | 50 | 10.8 | 88 | 11.8 | 36 | 40.9 | 9 |
| 40- 49 | 28 | 9.9 | 48 | 10.4 | 76 | 10.2 | 43 | 56.6 | 6 |
| 50- 59 | 17 | 6.0 | 33 | 7.1 | 50 | 6.7 | 33 | 66.0 | 6 |
| 60- 69 | 14 | 4.9 | 13 | 2.8 | 27 | 3.6 | 18 | 66.7 | 3 |
| 70- 79 | 4 | 1.4 | 12 | 2.6 | 16 | 2.1 | 12 | 75.0 | 2 |
| 80- 89 | 3 | 1.1 | 5 | 1.1 | 8 | 1.1 | 5 | 62.5 | 0 |
| 90- 99 | 5 | 1.8 | 5 | 1.1 | 10 | 1.3 | 8 | 80.0 | 0 |
| 100-109 | ... | ... | 3 | 0.6 | 3 | 0.4 | 2 | 66.7 | 0 |
| 110-119 | ... | ... | 3 | 0.6 | 3 | 0.4 | 2 | 66.7 | 0 |
| 120-129 | ... | ... | 3 | 0.6 | 3 | 0.4 | 2 | 66.7 | 0 |
| 155-366 | 2 | 0.7 | 17 | 3.7 | 19 | 2.6 | 10 | 52.6 | 0 |
| > 366 | 4 | 1.4 | 12 | 2.6 | 16 | 2.1 | 10 | 62.5 | 3 |
| All periods | 186 | 65.7 | 331 | 71.6 | 517 | 69.4 | 253 | 48.9 | 37 |

TABLE 4.--Release and recovery points of drift bottles released June 17, 1931, at 27 stations on the transect, Chicago, Illinois to St. Joseph, Michigan

| Station number | Station of release | | Recoveries | | | | | Drag attached[1] |
|---|---|---|---|---|---|---|---|---|
| | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| 1 | 41° 54.1' | 87° 30.8' | August 6 | 43° 1.0' | 86° 13.9' | 50 | 100 | Yes |
| 2 | 41° 54.7' | 87° 28.6' | August 23 | 43° 17.8' | 87° 53.7' | 67 | 97 | No |
| 3 | 41° 54.9' | 87° 26.1' | ... | ... | ... | ... | ... | ... |
| 4 | 41° 55.6' | 87° 24.2' | August 21 | 42° 11.0' | 87° 46.7' | 65 | 26 | No |
| 5 | 41° 55.9' | 87° 22.0' | September 1 | 43° 20.2' | 86° 25.0' | 76 | 107 | ? |
| 6 | 41° 56.5' | 87° 19.5' | July 29 | 42° 15.5' | 86° 21.7' | 42 | 54 | No |
| 7 | 41° 57.0' | 87° 17.3' | July 29 | 42° 36.8' | 86° 14.4' | 42 | 71 | No |
| 8 | 41° 57.3' | 87° 14 9' | July 30 | 42° 21.4' | 86° 13.5' | 43 | 56 | No |
| 9 | 41° 58.0' | 87° 12.3' | ... | ... | ... | ... | ... | ... |
| 10 | 41° 58.4' | 87° 9.8' | August 2 | 42° 9.4' | 86° 27.3' | 46 | 42 | No |
| 11 | 41° 59.1' | 87° 7.4' | August 22 | 41° 37.6' | 87° 13.5' | 66 | 26 | Yes |
| 12 | 42° 0.0' | 87° 5.0' | ... | ... | ... | ... | ... | ... |
| 13 | 42° 0.4' | 87° 2.5' | August 10 | 41° 38.0' | 87° 10.7' | 54 | 27 | Yes |
| 14 | 42° 0.9' | 87° 0.0' | July 11 | 42° 7.7' | 86° 28.5' | 24 | 30 | No |
| 15 | 42° 1.4' | 86° 57.9' | August 1 | 42° 16.8' | 87° 49.7' | 45 | 48 | No |
| 16 | 42° 1.8' | 86° 55.2' | July 30 | 41° 40.5' | 87° 27.8' | 43 | 38 | Yes |
| 17 | 42° 2.5' | 86° 53.0' | ... | ... | ... | ... | ... | ... |
| 18 | 42° 2.9' | 86° 50.7' | August 25 | 41° 37.7' | 87° 11.6' | 69 | 35 | ? |
| 19 | 42° 3.4' | 86° 48.4' | July 29 | 42° 1.3' | 86° 33.2' | 42 | 14 | Yes |
| 20 | 42° 3.6' | 86° 46.2' | July 23 | 42° 18.8' | 86° 19.6' | 36 | 28 | Yes |
| 21 | 42° 3.9' | 86° 43.7' | July 21 | 42° 59.4' | 86° 13.5' | 34 | 67 | Yes |
| 22 | 42° 4.7' | 86° 41.0' | July 30 | 42° 0.3' | 86° 33.6' | 43 | 9 | No |
| 23 | 42° 5.2' | 86° 38.9' | July 13 | 43° 21.7' | 86° 25.3' | 26 | 86 | No |
| 24 | 42° 5.8' | 86° 36.5' | July 13 | 43° 39.1' | 86° 33.0' | 26 | 108 | ? |
| 25 | 42° 6.0' | 86° 34.6' | July 11 | 44° 9.4' | 86° 24.5' | 24 | 144 | Yes |
| 26 | 42° 6.4' | 86° 32.5' | July 4 | 44° 7.5' | 86° 26.2' | 17 | 140 | No |
| 27 | 42° 6.7' | 86° 30.6' | July 13 | 42° 59.4' | 86° 13.5' | 26 | 61 | No |
| Average | ... | ... | ... | ... | ... | 43.7 | 61.5 | ... |
| Number recovered | ... | ... | ... | ... | ... | 23 | 23 | ... |

[1] With drags, 8; without drags, 12; no data, 3.

Figure 4.--Movements of bottles released along the transect, Chicago to St. Joseph, June 17, 1931.

Four bottles from the central part landed on the southern coast and three moved to the western coast; one was taken as far as 6 miles south of Port Washington, Wisconsin. Some of the eastern bottles had floated more than 60 miles along the Michigan shore within 26 days.

## St. Joseph to Grand Haven to Nets

Sixteen bottles (94 percent) were recovered from the 17 released June 18 and 22, 1931 (table 5), along the Michigan shore (fig. 5). Seven (44 percent) of the 16 bottles had retained the drag. The recoveries were recorded over a period of 5-93 days, an average of 32.6. The minimum distances of travel were 15-160 miles, an average of 80.6.

Thirteen bottles were scattered northward from $3\frac{1}{2}$ miles north of South Haven to the North Manitou Island--two landed to the southeast down to three-quarters of a mile north of Bridgman; and one floated to the western shore at the Great Lakes Naval Station (Illinois). The fact that eight bottles floated beyond 75

TABLE 5.--Release and recovery points of drift bottles released in 1931 between St. Joseph and Grand Haven, Michigan (June 18--13 stations), and between Grand Haven and nets (June 22--4 stations)

| Station number | Station of release | | Recoveries | | | | | Drag attached [1] |
|---|---|---|---|---|---|---|---|---|
| | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| June 18 | | | | | | | | |
| 28 | 42° 17.5' | 86° 37.5' | August 19 | 41° 56.7' | 86° 35.1' | 62 | 24 | No |
| 29 | 42° 17.5' | 86° 37.5' | August 1 | 42° 19.2' | 87° 49.0' | 44 | 60 | Yes |
| 30 | 42° 23.3' | 86° 41.7' | July 20 | 42° 17.0' | 86° 21.2' | 32 | 20 | No |
| 31 | 42° 23.3' | 86° 41.7' | July 22 | 42° 26.9' | 86° 15.2' | 34 | 23 | Yes |
| 32 | 42° 28.0' | 86° 39.3' | July 20 | 42° 59.6' | 86° 13.7' | 32 | 40 | Yes |
| 33 | 42° 32.0' | 86° 36.7' | ... | ... | ... | ... | ... | ... |
| 34 | 42° 36.3' | 86° 34.5' | July 14 | 43° 2.7' | 86° 15.5' | 26 | 33 | No |
| 35 | 42° 40.1' | 86° 32.2' | July 14 | 43° 51.8' | 86° 26.5' | 26 | 83 | No |
| 36 | 42° 44.4' | 86° 29.8' | July 8 | 44° 13.3' | 86° 26.9' | 20 | 104 | No |
| 37 | 42° 48.5' | 86° 27.3' | July 13 | 44° 47.3' | 86° 4.8' | 25 | 142 | No |
| 38 | 42° 52.4' | 86° 25.1' | September 19 | 45° 7.3' | 86° 3.8' | 93 | 160 | No |
| 39 | 42° 57.0' | 86° 22.8' | July 8 | 44° 55.0' | 86° 2.7' | 20 | 140 | Yes |
| 40 | 43° 0.7' | 86° 20.1' | June 23 | 43° 14.7' | 86° 21.6' | 5 | 15 | Yes |
| June 22 | | | | | | | | |
| 41 | 43° 7.0' | 86° 23.7' | July 8 | 44° 51.8' | 86° 4.0' | 20 | 127 | Yes |
| 42 | 43° 7.0' | 86° 23.7' | July 15 | 45° 6.7' | 86° 3.8' | 27 | 144 | Yes |
| 43 | 43° 10.8' | 86° 31.7' | July 18 | 44° 35.7' | 86° 12.4' | 30 | 100 | No |
| 44 | 43° 10.8' | 86° 31.7' | July 14 | 44° 12.6' | 86° 26.9' | 26 | 75 | No |
| Average | ... | ... | ... | ... | ... | 32.6 | 80.6 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 16 | 16 | ... |

[1] With drags, 7; without drags, 9.

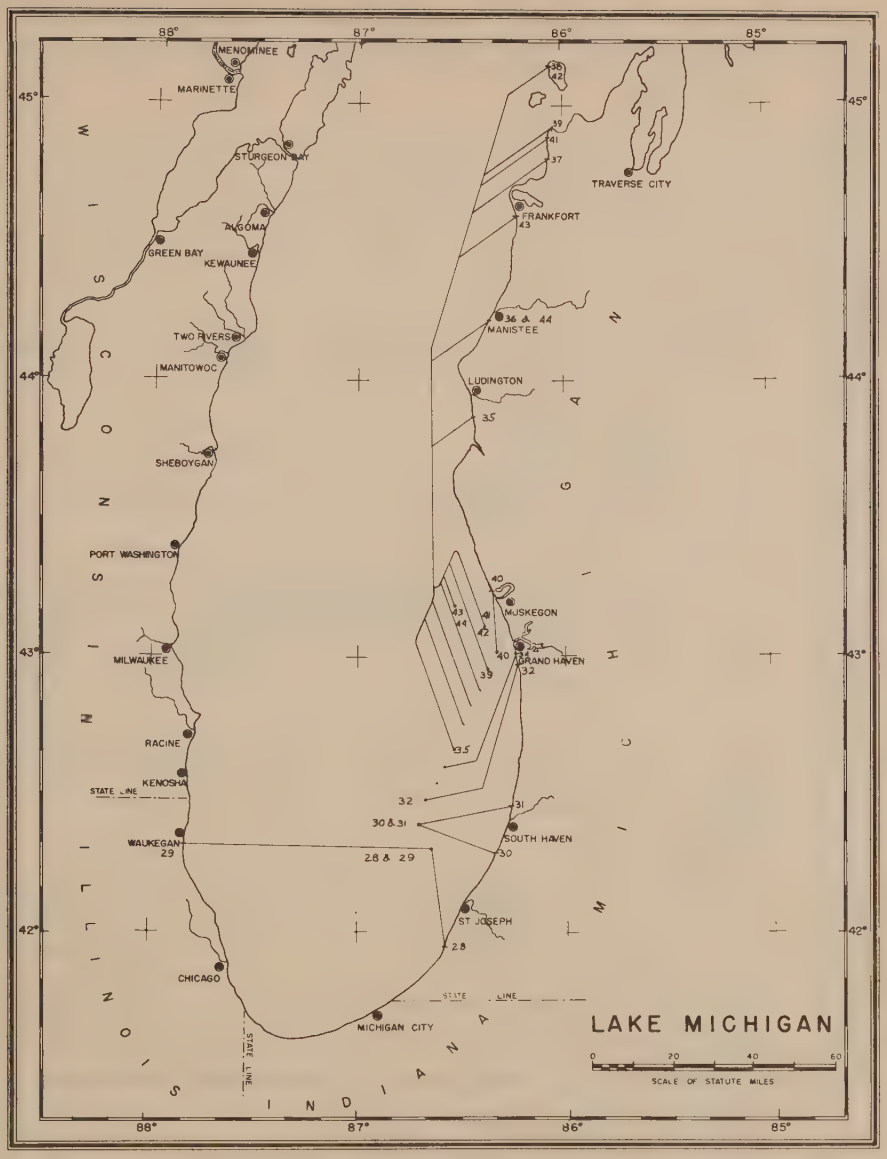



Figure 5.--Movements of bottles released between St. Joseph and Grand Haven, June 18, and between Grand Haven and nets, June 22, 1931.

miles along the Michigan shore within 30 days gives evidence of a strong northerly current.

## Ludington to Nets and Manistee to Two Rivers

Four bottles were released off Ludington on June 23, 1931, and 27 were dropped on June 24 (table 6) along the Manistee to Two Rivers transect (fig. 6). Twenty-five bottles (81 percent) were recovered--24 during a period of 10-57 days and 1 in 298 days. The average was 27.3 days for 24 bottles and 38.1 days for 25; 16 of them were landed within 30 days. All of the bottles had drifted northeast from about 1 mile north of Walther League Camp near Arcadia to Cross Village (Weikamp Creek), except the last one (no. 75) that was found in Wisconsin off Centerville, 14 miles north of Sheboygan. The minimum distances of movement ranged from 18-136 miles and averaged 79.8 miles. Although the bottles moved

TABLE 6.--Release and recovery points of drift bottles released in 1931 off Ludington (June 23--4 stations), and on the transect, Manistee, Michigan, to Two Rivers, Wisconsin (June 24--27 stations).

[ Asterisk indicates recovery in years beyond 1931; no. 56 was recovered April 17, 1932 ]

| Station number | Station of release | | Recoveries | | | | | Drag attached [1] |
|---|---|---|---|---|---|---|---|---|
| | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| June 23 | | | | | | | | |
| 45 | 43° 55.6' | 86° 36.5' | ... | ... | ... | ... | ... | ... |
| 46 | 43° 55.6' | 86° 36.5' | July 5 | 44° 56.4' | 85° 50.8' | 12 | 87 | No |
| 47 | 43° 55.0' | 86.41.1' | .... | ... | ... | ... | ... | ... |
| 48 | 43° 55.0' | 86° 41.1' | ... | ... | ... | ... | ... | ... |
| June 24 | | | | | | | | |
| 49 | 44° 14.8' | 86° 23.2' | July 8 | 44° 53.6' | 86° 4.4' | 14 | 52 | Yes |
| 50 | 44° 14.7' | 86° 25.7' | July 14 | 45° 23.4' | 84° 54.7' | 20 | 120 | No |
| 51 | 44° 14.6' | 86° 28.0' | July 4 | 44° 55.5' | 85° 57.9' | 10 | 55 | Yes |
| 52 | 44° 14.4' | 86° 30.4' | July 21 | 44° 54.3' | 85° 58.4' | 27 | 58 | Yes |
| 53 | 44° 14.0' | 86° 32.8' | July 12 | 45° 12.4' | 85° 32.3' | 18 | 86 | No |
| 54 | 44° 13.8' | 86° 35.3' | July 15 | 45° 1.5' | 85° 45.9' | 21 | 70 | No |
| 55 | 44° 13.6' | 86° 37.8' | July 22 | 44° 59.5' | 85° 46.7' | 28 | 72 | No |
| 56 | 44° 13.4' | 86° 40.4' | April 17* | 45° 15.0' | 85° 23.0' | 298 | 98 | No |
| 57 | 44° 13.3' | 86° 43.0' | August 6 | 45° 22.9' | 84° 55.8' | 43 | 128 | No |
| 58 | 44° 13.1' | 86° 45.5' | July 22 | 45° 4.9' | 86° 2.0' | 28 | 78 | Yes |
| 59 | 44° 12.9' | 86° 47.9' | July 26 | 44° 54.3' | 85° 59.6' | 32 | 65 | No |
| 60 | 44° 12.6' | 86° 50.3' | July 15 | 44° 56.4' | 85° 49.8' | 21 | 76 | Yes |
| 61 | 44° 12.4' | 86° 52.9' | ... | ... | ... | ... | ... | ... |
| 62 | 44° 12.3' | 86° 55.2' | July 25 | 45° 39.0' | 85° 1.6' | 31 | 136 | Yes |
| 63 | 44° 12.0' | 86° 56.8' | July 13 | 44° 39.5' | 86° 15.2' | 19 | 57 | No |
| 64 | 44° 11.8' | 86° 59.2' | July 13 | 44° 38.3' | 86° 14.4' | 19 | 57 | Yes |
| 65 | 44° 11.5' | 87° 1.9' | July 29 | 45° 22.9' | 84° 55.8' | 35 | 136 | Yes |
| 66 | 44° 10.9' | 87° 4.7' | August 1 | 45° 22.5' | 85° 8.3' | 38 | 126 | No |
| 67 | 44° 10.7' | 87° 7.8' | July 15 | 44° 37.3' | 86° 13.8' | 21 | 54 | Yes |
| 68 | 44° 10.5' | 87° 10.7' | ... | ... | ... | ... | ... | ... |
| 69 | 44° 10.3' | 87° 13.6' | July 23 | 44° 54.3' | 85° 58.4' | 29 | 79 | No |
| 70 | 44° 10.0' | 87° 16.3' | August 2 | 44° 55.0' | 85° 57.7' | 39 | 81 | No |
| 71 | 44° 9.6' | 87° 19.5' | July 28 | 44° 34.4' | 86° 13.7' | 34 | 60 | No |
| 72 | 44° 9.4' | 87° 22.6' | July 24 | 44° 30.0' | 86° 14.0' | 30 | 59 | No |
| 73 | 44° 9.3' | 87° 24.5' | July 23 | 44° 56.8' | 85° 56.3' | 29 | 88 | No |
| 74 | 44° 8.9' | 87° 27.8' | ... | ... | ... | ... | ... | ... |
| 75 | 44° 8.6' | 87° 30.7' | August 20 | 43° 55.3' | 87° 44.0' | 57 | 18 | No |
| Average | ... | ... | ... | ... | ... | 38.1 | 79.8 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 25 | 25 | ... |

[1] With drags, 9; without drags, 16.

Figure 6.--Movements of bottles released off Ludington, June 23, and along the transect, Manistee to Two Rivers, June 24, 1931.

northward none had entered Traverse Bay or reached the Straits of Mackinaw. Nine (36 percent) of the bottles retained their drags.

## Sheboygan to Sheboygan Reef to Racine

Forty-two bottles (table 7) were released June 26 and 27, 1931, in Wisconsin from Sheboygan to Sheboygan Reef to Racine (fig. 7). Of the 29 (69 percent) bottles recovered 11 moved northeast, 7 southeast, 3 east, 7 southwest, and 1 northwest. Twenty-one bottles that crossed the lake floated 37-124 minimum miles, an average of 60.7, and were scattered along the Michigan shore from 7 miles north of Holland to 3 miles southwest of Good Harbor. It is unusual that 18 of these bottles had moved to the same extended area across the lake. The other eight bottles ranged from Lake Forest, Illinois, to 9 miles north of Sheboygan, Wisconsin, and had floated from 2-55 miles, an average of 24.4. All but three of the bottles in Michigan were found in 32 days and all but one on the west coast in 61 days. Only six (23 percent) of 26 bottles kept the drag.

TABLE 7.--Release and recovery points of drift bottles released in 1931 from Sheboygan to Sheboygan Reef (June 26 and 27--17 stations) and from Sheboygan Reef to Racine (June 27--25 stations)

| Station number | Station of release | | Recoveries | | | | | Drag attached[1] |
|---|---|---|---|---|---|---|---|---|
| | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| June 26 | | | | | | | | |
| 76 | 43° 43.9' | 87° 40.0' | August 26 | 43° 44.1' | 87° 42.7' | 61 | 2 | No |
| 77 | 43° 42.7' | 87° 38.0' | ... | ... | ... | ... | ... | ... |
| 78 | 43° 41.7' | 87° 36.1' | August 23 | 43° 52.9' | 87° 43.2' | 58 | 13 | ... |
| 79 | 43° 40.5' | 87° 34.3' | August 28 | 43° 18.8' | 87° 54.4' | 63 | 30 | No |
| 80 | 43° 39.6' | 87° 32.4' | ... | ... | ... | ... | .... | ... |
| 81 | 43° 38.4' | 87° 30.1' | August 11 | 44° 56.4' | 85° 50.8' | 46 | 124 | No |
| 82 | 43° 37.2' | 87° 27.7' | ... | ... | ... | ... | ... | ... |
| June 27 | | | | | | | | |
| 83 | 43° 35.8' | 87° 26.0' | ... | ... | ... | ... | ... | ... |
| 84 | 43° 34.8' | 87° 24.3' | July 30 | 43° 9.4' | 86° 18.2' | 34 | 62 | Yes |
| 85 | 43° 33.7' | 87° 22.2' | ... | ... | ... | ... | ... | ... |
| 86 | 43° 32.6' | 87° 20.3' | July 24 | 43° 20.8' | 86° 25.1' | 28 | 49 | No |
| 87 | 43° 31.6' | 87° 18.7' | July 29 | 42° 59.6' | 86° 13.7' | 33 | 66 | Yes |
| 88 | 43° 30.4' | 87° 16.7' | ... | ... | ... | ... | ... | ... |
| 89 | 43° 29.4' | 87° 14.8' | July 29 | 42° 52.4' | 86° 13.6' | 33 | 67 | Yes |
| 90 | 43° 28.4' | 87° 12.8' | July 28 | 43° 6.5' | 86° 17.0' | 32 | 54 | Yes |
| 91 | 43° 27.0' | 87° 11.1' | ... | ... | ... | ... | ... | ... |
| 92 | 43° 26.0' | 87° 9.5' | July 27 | 43° 10.8' | 86° 19.3' | 31 | 46 | ? |
| 93 | 43° 24.8' | 87° 11.0' | ... | ... | ... | ... | ... | ... |
| 94 | 43° 23.5' | 87° 11.8' | July 29 | 43° 32.3' | 86° 29.5' | 33 | 37 | No |
| 95 | 43° 21.6' | 87° 13.4' | ... | ... | ... | ... | ... | ... |
| 96 | 43° 20.4' | 87° 14.8' | ... | ... | ... | ... | ... | ... |
| 97 | 43° 18.7' | 87° 15.7' | July 27 | 43° 23.0' | 86° 26.4' | 31 | 43 | No |
| 98 | 43° 17.3' | 87° 17.2' | July 27 | 43° 13.3' | 86° 20.3' | 31 | 48 | ? |
| 99 | 43° 16.6' | 87° 18.4' | July 21 | 43° 38.7' | 86° 32.9' | 25 | 46 | No |
| 100 | 43° 14.0' | 87° 19.5' | September 30 | 44° 3.2' | 86° 30.9' | 96 | 68 | No |
| 101 | 43° 12.6' | 87°20.8' | ... | ... | ... | ... | ... | ... |
| 102 | 43° 11.1' | 87° 22.0' | July 22 | 43° 36.2' | 86° 32.3' | 26 | 50 | No |
| 103 | 43° 9.4' | 87° 24.5' | July 20 | 43° 21.7' | 86° 25.3' | 24 | 51 | Yes |
| 104 | 43° 7.8' | 87° 25.5' | July 27 | 43° 9.9' | 86° 18.8' | 31 | 57 | No |
| 105 | 43° 6.3' | 87° 26.7' | August 28 | 42° 57.5' | 87° 50.4' | 63 | 23 | No |
| 106 | 43° 4.5' | 87° 28.1' | July 31 | 43° 33.5' | 86° 32.4' | 35 | 68 | No |
| 107 | 43° 3.9' | 87° 29.5' | July 27 | 43° 9.7' | 86° 18.4' | 31 | 59 | No |
| 108 | 43° 1.3' | 87° 30.7' | July 28 | 43° 33.4' | 86° 30.7' | 32 | 61 | No |
| 109 | 42° 59.7' | 87° 31.9' | August 25 | 42° 15.5' | 87° 49.3' | 60 | 55 | No |
| 110 | 42° 58.4' | 87° 33.2' | July 30 | 43° 25.7' | 86° 26.8' | 34 | 63 | No |
| 111 | 42° 57.2' | 87° 34.6' | July 30 | 43° 25.7' | 86° 26.8' | 34 | 65 | No |
| 112 | 42° 55.5' | 87° 35.6' | ... | ... | ... | ... | ... | ... |
| 113 | 42° 53.9' | 87° 37.1' | August 22 | 42° 27.4' | 87° 47.6' | 57 | 33 | No |
| 114 | 42° 52.2' | 87° 38.1' | August 27 | 42° 36.8' | 87° 49.3' | 62 | 21 | Yes |
| 115 | 42° 50.5' | 87° 39.2' | September 26 | 43° 49.7' | 86° 25.9' | 92 | 90 | No |
| 116 | 42° 49.1' | 87° 40.3' | ... | ... | ... | ... | ... | ... |
| 117 | 42° 47.4' | 87° 41.8' | July 11 | 42° 32.0' | 87° 48.8' | 15 | 18 | No |
| Average | ... | ... | ... | ... | ... | 42.4 | 50.6 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 29 | 29 | ... |

[1]With drags, 6; without drags, 20.

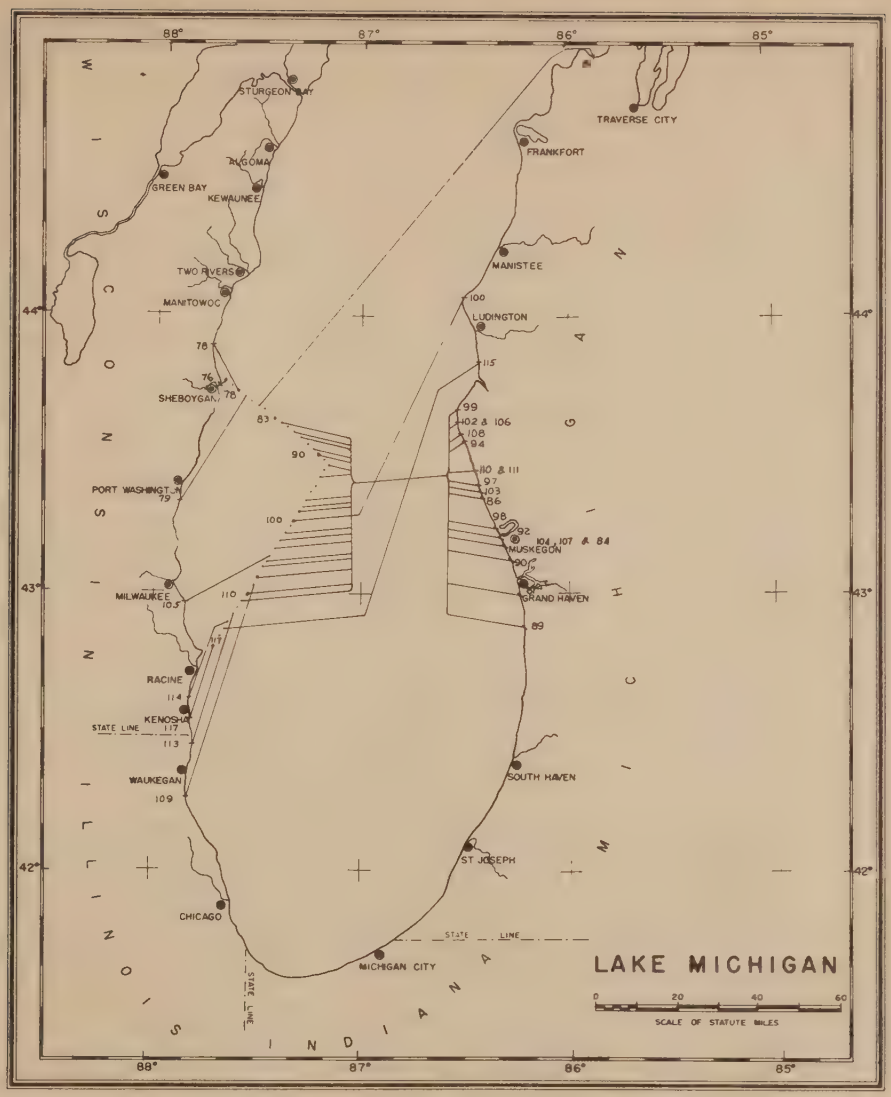



Figure 7.--Movements of bottles released from Sheboygan to Sheboygan Reef, June 26 and 27, and from Sheboygan Reef to Racine, June 27, 1931.

## Waukegan to St. Joseph

Of the 30 bottles (table 8) released along the transect on June 30, 1931, 24 (80 percent) were recovered (fig. 8). Eight were collected along the southern shore in Indiana, two moved southwest, seven northwest, two southeast, and five northeast.

The nine bottles from the western part were discovered from near Highland Park, Illinois, to Sheboygan, Wisconsin. Their travel ranged from 7-95 miles, an average of 48.0, in 5-57 days, an average of 42.1. The eight bottles recovered toward the south landed in 41-57 days, an average of 47.5, and reached the shores at distances of 33-50 miles, an average of 40.9. The seven recoveries along the eastern shore extended from 6 miles south of St. Joseph, Michigan, to Big Sable Light, 8 miles north of Ludington, Michigan. Six of these bottles traveled 32-68 miles, an average of 48.8, and were recovered in 29-60 days, an average of 51.8; the seventh one was found 130 miles distant and was discovered on the 94th day.

TABLE 8.--Release and recovery points of drift bottles released June 30, 1931, at 30 stations on the transect, Waukegan, Illinois, to St. Joseph, Michigan

| Station of release | | | Recoveries | | | | | Drag attached |
|---|---|---|---|---|---|---|---|---|
| Station number | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| 118 | 42° 21.4' | 87° 46.6' | July 5 | 42° 14.7' | 87° 48.9' | 5 | 7 | Yes |
| 119 | 42° 20.8' | 87° 43.5' | August 11 | 43° 40.7' | 87° 42.8' | 42 | 92 | No |
| 120 | 42° 20.4' | 87° 41.3' | August 13 | 43° 44.1' | 87° 42.7' | 44 | 95 | No |
| 121 | 42° 20.0' | 87° 39.0' | August 26 | 42° 35.2' | 87° 48.8' | 57 | 19 | No |
| 122 | 42° 19.6' | 87° 36.7' | ... | ... | ... | ... | ... | ... |
| 123 | 42° 19.4' | 87° 34.1' | August 12 | 42° 26.4' | 87° 48.1' | 43 | 15 | No |
| 124 | 42° 19.0' | 87° 32.3' | ... | ... | ... | ... | ... | ... |
| 125 | 42° 18.7' | 87° 29.3' | ... | ... | ... | ... | ... | ... |
| 126 | 42° 18.3' | 87° 27.0' | October 2 | 44° 3.8' | 86° 31.2' | 94 | 130 | No |
| 127 | 42° 17.7' | 87° 24.9' | August 24 | 42° 10.3' | 87° 46.4' | 55 | 20 | No |
| 128 | 42° 17.2' | 87° 22.6' | August 25 | 43° 11.5' | 87° 53.7' | 56 | 63 | No |
| 129 | 42° 16.6' | 87° 21.4' | August 29 | 42° 35.0' | 86° 13.5' | 60 | 62 | No |
| 130 | 42° 16.2' | 87° 18.0' | August 29 | 42° 13.8' | 86° 22.7' | 60 | 49 | No |
| 131 | 42° 15.8' | 87° 15.7' | August 26 | 42° 1.8' | 86° 31.1' | 57 | 42 | No |
| 132 | 42° 15.1' | 87° 12.5' | August 26 | 41° 37.3' | 87° 17.8' | 57 | 44 | No |
| 133 | 42° 14.7' | 87° 10.4' | August 29 | 42° 57.6' | 86° 14.1' | 60 | 68 | No |
| 134 | 42° 14.4' | 87° 7.9' | July 29 | 42° 13.4' | 86° 23.5' | 29 | 40 | No |
| 135 | 42° 13.9' | 87° 5.7' | August 14 | 42° 0.7' | 86° 33.4' | 45 | 32 | No |
| 136 | 42° 13.4' | 87° 3.2' | ... | ... | ... | ... | ... | ... |
| 137 | 42° 13.0' | 87° 0.9' | August 10 | 41° 37.3' | 87° 17.8' | 41 | 44 | No |
| 138 | 42° 12.6' | 86° 58.8' | August 13 | 41° 44.6' | 86° 52.2' | 44 | 33 | No |
| 139 | 42° 12.0' | 86° 56.4' | August 13 | 41° 40.7' | 87° 29.1' | 44 | 44 | Yes |
| 140 | 42° 11.6' | 86° 54.0' | August 11 | 41° 40.3' | 87° 2.8' | 42 | 37 | Yes |
| 141 | 42° 11.3' | 86° 51.7' | August 13 | 41° 39.3' | 87° 6.3' | 44 | 39 | No |
| 142 | 42° 10.7' | 86° 49.5' | ... | ... | ... | ... | ... | ... |
| 143 | 42° 10.4' | 86° 47.0' | August 21 | 41° 42.7' | 87° 31.6' | 52 | 50 | Yes |
| 144 | 42° 10.0' | 86° 44.6' | August 1 | 42° 13.8' | 87° 48.4' | 32 | 56 | No |
| 145 | 42° 9.5' | 86° 42.4' | August 14 | 42° 28.1' | 87° 47.8' | 45 | 60 | No |
| 146 | 42° 8.9' | 86° 39.0' | August 25 | 41° 41.5' | 86° 59.9' | 56 | 36 | No |
| 147 | 42° 8.4' | 86° 36.8' | ... | ... | ... | ... | ... | ... |
| Average | ... | ... | ... | ... | ... | 48.5 | 49.2 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 24 | 24 | ... |

[1] With drags, 4; without drags, 19.

Figure 8.--Movements of bottles released along the transect, Waukegan to St. Joseph, June 30, 1931.

Only three bottles moved more than 90 miles; all others were taken within 70 miles. Ten of the bottles were recovered in 41-45 days and nine between 55 and 60 days. Most of the former were found on the south and west shores; the latter were distributed on all coasts but mostly on the east shore. Only four (17 percent) of the 23 bottles retained the drag.

## Racine to Grand Haven

Of the 36 bottles (table 9) released on July 17, 1931, along the transect (fig. 9) 27 (75 percent) were recovered. Only six (22 percent) of these bottles held the drags. The bottles had covered minimum distances from 3-121 miles, an average of 44.2, during a period of 12-96 days, an average of 46.3. Half of the bottles from the western part of the transect and all from the eastern landed on the Michigan shore, a total of 20. Along the western shore, three bottles scattered northwest as far as Sheboygan, Wisconsin, and four drifted southwest as far as $1\frac{1}{2}$ miles south of Highland Park, Illinois. On the eastern shore, eight were distributed southeast down to St. Joseph,

TABLE 9.--Release and recovery points of drift bottles released July 17, 1931, at 36 stations on the transect, Racine, Wisconsin, to Grand Haven, Michigan

| Station of release | | | Recoveries | | | | | Drag attached [1] |
|---|---|---|---|---|---|---|---|---|
| Station number | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| 148 | 42° 44.8' | 87° 43.5' | August 2 | 43° 31.3' | 87° 48.0' | 16 | 54 | Yes |
| 149 | 42° 45.0' | 87° 41.3' | September 14 | 43° 3.4' | 87° 52.8' | 59 | 23 | No |
| 150 | 42° 45.6' | 87° 38.2' | October 21 | 44° 4.4' | 86° 30.6' | 96 | 106 | No |
| 151 | 42° 46.1' | 87° 35.9' | October 2 | 43° 21.7' | 86° 25.3' | 77 | 72 | No |
| 152 | 42° 46.8' | 87° 33.5' | ... | ... | ... | ... | ... | ... |
| 153 | 42° 47.4' | 87° 30.9' | August 31 | 43° 12.2' | 86° 20.0' | 45 | 67 | No |
| 154 | 42° 48.1' | 87° 28.6' | September 17 | 43° 45.7' | 87° 42.5' | 62 | 67 | Yes |
| 155 | 42° 48.7' | 87° 26.6' | ... | ... | ... | ... | ... | ... |
| 156 | 42° 49.0' | 87° 24.2' | ... | ... | ... | ... | ... | ... |
| 157 | 42° 49.6' | 87° 21.8' | August 20 | 42° 10.0' | 87° 45.9' | 34 | 49 | No |
| 158 | 42° 50.2' | 87° 19.4' | August 18 | 42° 39.5' | 87° 48.8' | 32 | 27 | No |
| 159 | 42° 50.7' | 87° 16.8' | August 20 | 42° 22.6' | 87°49.0' | 34 | 41 | No |
| 160 | 42° 51.3' | 87° 14.4' | August 27 | 42° 24.7' | 87° 48.2' | 41 | 40 | Yes |
| 161 | 42° 51.9' | 87° 11.8' | October 2 | 44° 28.4' | 86° 14.5' | 77 | 121 | No |
| 162 | 42° 52.3' | 87° 9.6' | October 11 | 43° 33.0' | 86° 30.0' | 86 | 59 | No |
| 163 | 42° 52.8' | 87° 5.7' | ... | ... | ... | ... | ... | ... |
| 164 | 42° 53.4' | 87° 3.2' | October 8 | 42° 44.5' | 86° 12.1' | 83 | 45 | No |
| 165 | 42° 54.1' | 87° 0.7' | September 26 | 43° 44.9' | 86° 27.7' | 71 | 65 | No |
| 166 | 42° 54.7' | 86° 58.3' | ... | ... | ... | ... | ... | ... |
| 167 | 42° 55.3' | 86° 56.0' | ... | ... | ... | ... | ... | ... |
| 168 | 42° 55.7' | 86° 53.8' | August 30 | 42° 6.4' | 86° 30.0' | 44 | 60 | No |
| 169 | 42° 56.3' | 86° 51.3' | ... | ... | ... | ... | ... | ... |
| 170 | 42° 57.0' | 86° 48.8' | August 29 | 42° 6.7' | 86° 29.8' | 43 | 60 | No |
| 171 | 42° 57.5' | 86° 46.3' | August 5 | 43° 3.6' | 86° 15.4' | 19 | 27 | No |
| 172 | 42° 58.3' | 86° 43.0' | September 14 | 43° 3.6' | 86° 15.4' | 59 | 25 | No |
| 173 | 42° 58.8' | 86° 40.5' | ... | ... | ... | ... | ... | ... |
| 174 | 42° 59.3' | 86° 38.0' | August 29 | 42° 23.4' | 86° 17.7' | 43 | 46 | No |
| 175 | 42° 59.7' | 86° 35.8' | August 17 | 43° 2.7' | 86° 15.5' | 31 | 18 | Yes |
| 176 | 43° 0.0' | 86° 33.7' | August 30 | 42° 53.5' | 86° 13.3' | 44 | 19 | Yes |
| 177 | 43° 0.5' | 86° 31.3' | July 29 | 42° 46.6' | 86° 13.3' | 12 | 21 | No |
| 178 | 43° 1.2' | 86° 28.8' | August 30 | 43° 1.5' | 86° 15.1' | 44 | 12 | No |
| 179 | 43° 1.8' | 86° 26.4' | ... | ... | ... | ... | ... | ... |
| 180 | 43° 2.1' | 86° 24.2' | July 29 | 42° 43.2' | 86° 13.1' | 12 | 24 | No |
| 181 | 43° 2.6' | 86° 21.8' | August 10 | 42° 38.7' | 86° 14.0' | 24 | 29 | No |
| 182 | 43° 3.0' | 86° 19.9' | August 8 | 43° 2.7' | 86° 15.5' | 22 | 3 | Yes |
| 183 | 43° 3.3' | 86° 18.2' | August 26 | 43° 16.0' | 86° 23.0' | 40 | 13 | No |
| Average | ... | ... | ... | ... | ... | 46.3 | 44.2 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 27 | 27 | ... |

[1] With drags, 6; without drags, 21.

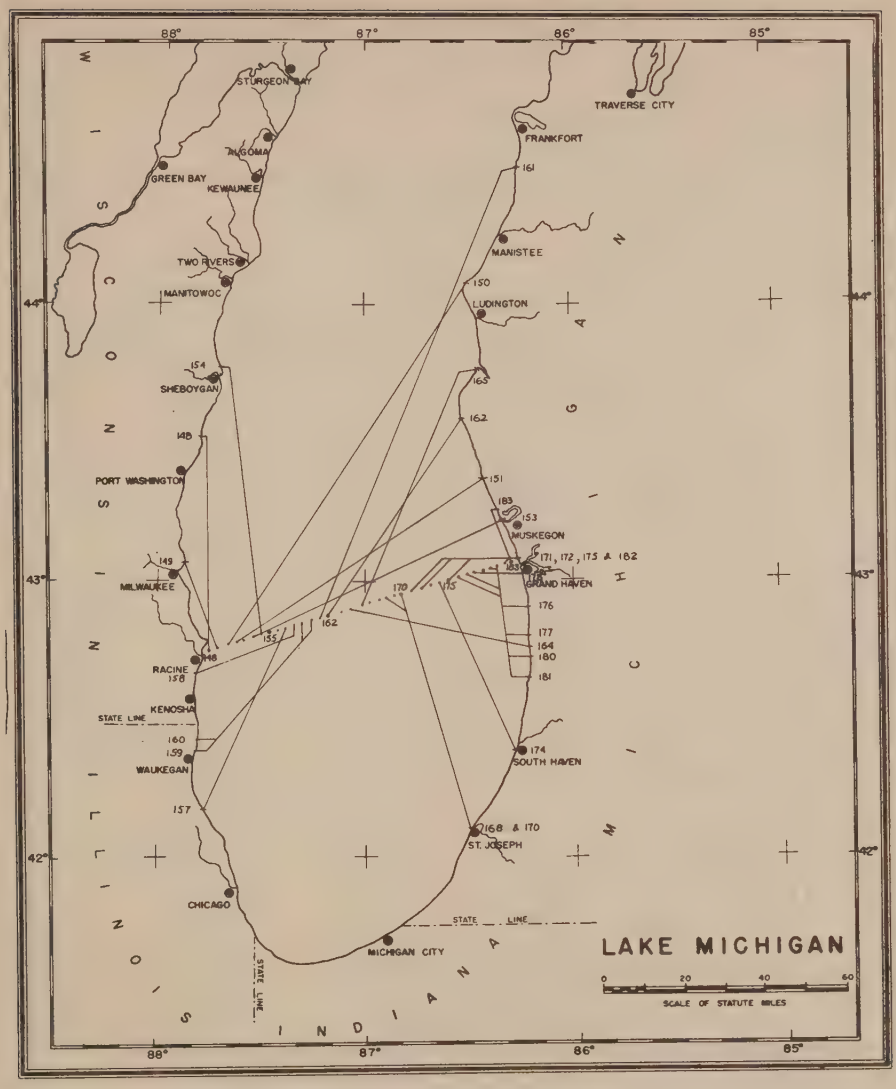



Figure 9.--Movements of bottles released along the transect, Racine to Grand Haven, July 17, 1931.

five moved eastward near Grand Haven, and seven were scattered northeast up to Arcadia. All five bottles recovered north of Muskegon had traveled between 59 and 121 miles and were not found until 71-96 days. These bottles perhaps had altered their direction after a change of the wind.

## Frankfort to Two Rivers to Nets

Twenty bottles (53 percent) were returned of the 38 (table 10) released along the transect on July 22 and near the nets off Two Rivers, July 23, 1931 (fig. 10). Eight (42 percent) of 19 bottles still possessed their drags. Seventeen bottles were recovered in 5-122 days, an average of 33.8, and the other three were found in 1933, 1935, and 1936. Minimum distances were 9-86 miles, an average of 37.0, for 17 bottles; the miles for the other 3 ranged from 104-185, an average of 134.7.

Thirteen bottles including four from the western part of the transect moved northeast and one southeast. They scattered from about 1½ miles north of Arcadia to the islands of

TABLE 10.--Release and recovery points of drift bottles released in 1931 on the transect, Frankfort, Michigan, to Two Rivers, Wisconsin (July 22--34 stations), and near the nets off Two Rivers (July 23--4 stations)

[Asterisk indicates recovery in years beyond 1931; no. 200 was recovered on July 22, 1936, no. 204 on April 8, 1935, and no. 217 on June 17, 1933]

| Station of release | | | Recoveries | | | | | Drag attached [1] |
|---|---|---|---|---|---|---|---|---|
| | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| July 22 | | | | | | | | |
| 184 | 44° 37.2' | 86° 15.8' | August 4 | 44° 51.1' | 86° 3.8' | 13 | 20 | No |
| 185 | 44° 36.4' | 86° 20.2' | ... | ... | ... | ... | ... | ... |
| 186 | 44° 35.6' | 86° 22.4' | August 11 | 44° 31.3' | 86° 13.7' | 20 | 9 | Yes |
| 187 | 44° 34.7' | 86° 25.0' | August 5 | 44° 42.1' | 86° 13.9' | 14 | 12 | Yes |
| 188 | 44° 33.8' | 86° 27.0' | August 20 | 44° 56.4' | 86° 50.8' | 29 | 46 | Yes |
| 189 | 44° 33.0' | 86° 29.6' | July 27 | 44° 37.3' | 86° 13.8' | 5 | 14 | No |
| 190 | 44° 32.3' | 86° 30.9' | August 1 | 44° 50.0' | 86° 2.7' | 10 | 39 | Yes |
| 191 | 44° 31.3' | 86° 33.5' | August 30 | 44° 56.8' | 85° 56.3' | 39 | 45 | No |
| 192 | 44° 30.5' | 86° 35.8' | ... | ... | ... | ... | ... | ... |
| 193 | 44° 29.5' | 86° 38.2' | ... | ... | ... | ... | ... | ... |
| 194 | 44° 28.6' | 86° 40.5' | September 19 | 45° 6.0' | 86° 3.2' | 59 | 54 | No |
| 195 | 44° 27.8' | 86° 42.7' | ... | ... | ... | ... | ... | ... |
| 196 | 44° 26.9' | 86° 45.3' | ... | ... | ... | ... | ... | ... |
| 197 | 44° 26.3' | 86° 47.9' | August 9 | 45° 22.7' | 85° 49.4' | 18 | 80 | No |
| 198 | 44° 25.3' | 86° 50.4' | ... | ... | ... | ... | ... | ... |
| 199 | 44° 24.5' | 86° 51.6' | ... | ... | ... | ... | ... | ... |
| 200 | 44° 23.7' | 86° 54.0' | July 22* | 45° 37.0' | 85° 38.0' | 1,825 | 104 | No |
| 201 | 44° 22.6' | 86° 55.2' | ... | ... | ... | ... | ... | ... |
| 202 | 44° 21.8' | 86° 58.8' | ... | ... | ... | ... | ... | ... |
| 203 | 44° 21.0' | 87° 1.1' | August 9 | 44° 58.1' | 85° 55.5' | 18 | 69 | Yes |
| 204 | 44° 20.1' | 87° 3.5' | April 8* | 45° 58.0' | 84° 32.0' | 1,355 | 185 | ? |
| 205 | 44° 19.4' | 87° 5.6' | November 21 | 45° 53.0' | 86° 19.8' | 122 | 115 | No |
| 206 | 44° 17.6' | 87° 8.0' | August 27 | 44° 21.6' | 87° 32.1' | 36 | 20 | No |
| 207 | 44° 17.4' | 87° 10.6' | ... | ... | ... | ... | ... | ... |
| 208 | 44° 16.7' | 87° 12.8' | ... | ... | ... | ... | ... | ... |
| 209 | 44° 16.0' | 87° 15.1' | ... | ... | ... | ... | ... | ... |
| 210 | 44° 15.0' | 87° 17.3' | ... | ... | ... | ... | ... | ... |
| 211 | 44° 14.3' | 87° 19.5' | August 13 | 44° 12.7' | 87° 30.3' | 21 | 11 | Yes |
| 212 | 44° 13.3' | 87° 20.5' | August 20 | 43° 45.7' | 87° 42.5' | 29 | 38 | Yes |
| 213 | 44° 12.6' | 87° 22.6' | ... | ... | ... | ... | ... | ... |
| 214 | 44° 11.8' | 87° 25.0' | ... | ... | ... | ... | ... | ... |
| 215 | 44° 10.9' | 87° 27.2' | August 24 | 44° 7.9' | 87° 36.2' | 33 | 10 | No |
| 216 | 44° 10.2' | 87° 29.3' | ... | ... | ... | ... | ... | ... |
| 217 | 44° 9.4' | 87° 31.6' | June 17* | 45° 0.0' | 86° 8.0' | 695 | 86 | Yes |
| July 23 | | | | | | | | |
| 218 | 44° 0.3' | 87° 23.4' | ... | ... | ... | ... | ... | ... |
| 219 | 44° 0.3' | 87° 23.4' | October 4 | 43° 28.5' | 87° 48.0' | 74 | 42 | No |
| 220 | 43° 55.7' | 87° 18.5' | August 25 | 43° 30.8' | 87° 47.5' | 34 | 34 | No |
| 221 | 43° 55.7' | 87° 18.5' | ... | ... | ... | ... | ... | ... |
| Average | ... | ... | ... | ... | ... | 33.8 | 37.0 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 17 | 17 | ... |

[1] With drags, 8; without drags, 11; no data, 1.

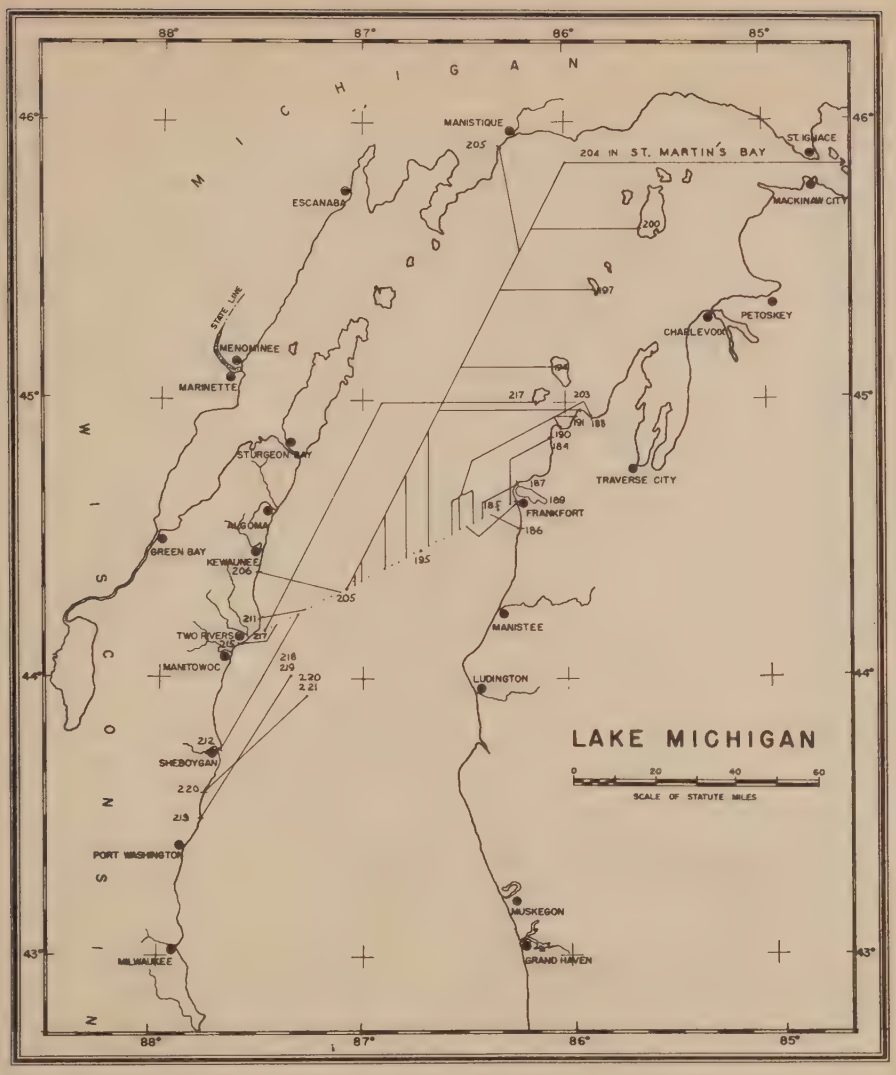



Figure 10.--Movements of bottles released along the transect, Frankfort to Two Rivers, July 22, and near the nets off Two Rivers, July 23, 1931.

northeastern Lake Michigan to south of Thompson; one was found in St. Martins Bay, Lake Huron. Only six bottles were recovered beyond Pyramid Point and three were discovered more than a year after release. One was found in Lake Huron 3.7 years later and two others in Lake Michigan after 1.9 and 5 years. Only five bottles were collected southwest and one northwest; they extended from 7 miles north of Port Washington to 7 miles south of Kewaunee.

## Frankfort to Kewaunee

Only seven (75 percent) of the 28 bottles dropped on July 30, 1931, were recovered along the transect (fig. 11 and table 11), and six of them (86 percent) had lost their drags. These few bottles were discovered in 10-80 days, an average of 36.4, and at a distance of 13-98 miles, an average of 55.1. Two bottles floated northeast, two northwest, and three southwest. The most northerly recovery was

TABLE 11.--Release and recovery points of drift bottles released July 30, 1931, at 28 stations on the transect, Frankfort, Michigan, to Kewaunee, Wisconsin

| Station of release | | | Recoveries | | | | | Drag attached [1] |
|---|---|---|---|---|---|---|---|---|
| Station number | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| 222 | 44° 36.3' | 86° 19.1' | August 27 | 43° 39.1' | 87° 42.9' | 28 | 96 | No |
| 223 | 44° 36.0' | 86° 21.5' | ... | ... | ... | ... | ... | ... |
| 224 | 44° 35.8' | 86° 24.0' | ... | ... | ... | ... | ... | ... |
| 225 | 44° 35.3' | 86° 26.8' | ... | ... | ... | ... | ... | ... |
| 226 | 44° 35.0' | 86° 29.3' | ... | ... | ... | ... | ... | ... |
| 227 | 44° 34.8' | 86° 32.1' | ... | ... | ... | ... | ... | ... |
| 228 | 44° 34.5' | 86° 34.6' | ... | ... | ... | ... | ... | ... |
| 229 | 44° 34.3' | 86° 37.2' | ... | ... | ... | ... | ... | ... |
| 230 | 44° 33.8' | 86° 39.8' | ... | ... | ... | ... | ... | ... |
| 231 | 44° 33.6' | 86° 42.5' | October 18 | 45° 52.3' | 86° 19.4' | 80 | 92 | No |
| 232 | 44° 33.3' | 86° 45.3' | ... | ... | ... | ... | ... | ... |
| 233 | 44° 32.9' | 86° 47.7' | ... | ... | ... | ... | ... | ... |
| 234 | 44° 32.6' | 86° 49.5' | September 19 | 45° 7.3' | 86° 3.8' | 51 | 54 | No |
| 235 | 44° 32.4' | 86° 52.4' | ... | ... | ... | ... | ... | ... |
| 236 | 44° 32.0' | 86° 54.9' | August 20 | 43° 18.8' | 87° 54.4' | 21 | 98 | No |
| 237 | 44° 31.7' | 86° 57.4' | ... | ... | ... | ... | ... | ... |
| 238 | 44° 31.3' | 87° 0.1' | ... | ... | ... | ... | ... | ... |
| 239 | 44° 30.9' | 87° 3.1' | ... | ... | ... | ... | ... | ... |
| 240 | 44° 30.5' | 87° 5.3' | ... | ... | ... | ... | ... | ... |
| 241 | 44° 30.2' | 87° 8.3' | ... | ... | ... | ... | ... | ... |
| 242 | 44° 29.9' | 87° 11.1' | ... | ... | ... | ... | ... | ... |
| 243 | 44° 29.5' | 87° 13.8' | ... | ... | ... | ... | ... | ... |
| 244 | 44° 29.0' | 87° 16.3' | ... | ... | ... | ... | ... | ... |
| 245 | 44° 28.7' | 87° 18.8' | ... | ... | ... | ... | ... | ... |
| 246 | 44° 28.5' | 87° 2-.6' | August 9 | 44° 14.3' | 87° 32.2' | 10 | 19 | Yes |
| 247 | 44° 28.3' | 87° 22.9' | August 29 | 44° 40.9' | 87° 21.3' | 30 | 14 | No |
| 248 | 44° 27.9' | 87° 25.4' | ... | ... | ... | ... | ... | ... |
| 249 | 44° 27.6' | 87° 27.3' | September 3 | 44° 39.3' | 87° 22.5' | 35 | 13 | No |
| Average | ... | ... | ... | ... | ... | 36.4 | 55.1 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 7 | 7 | ... |

[1] With drags, 1; without drags, 6.

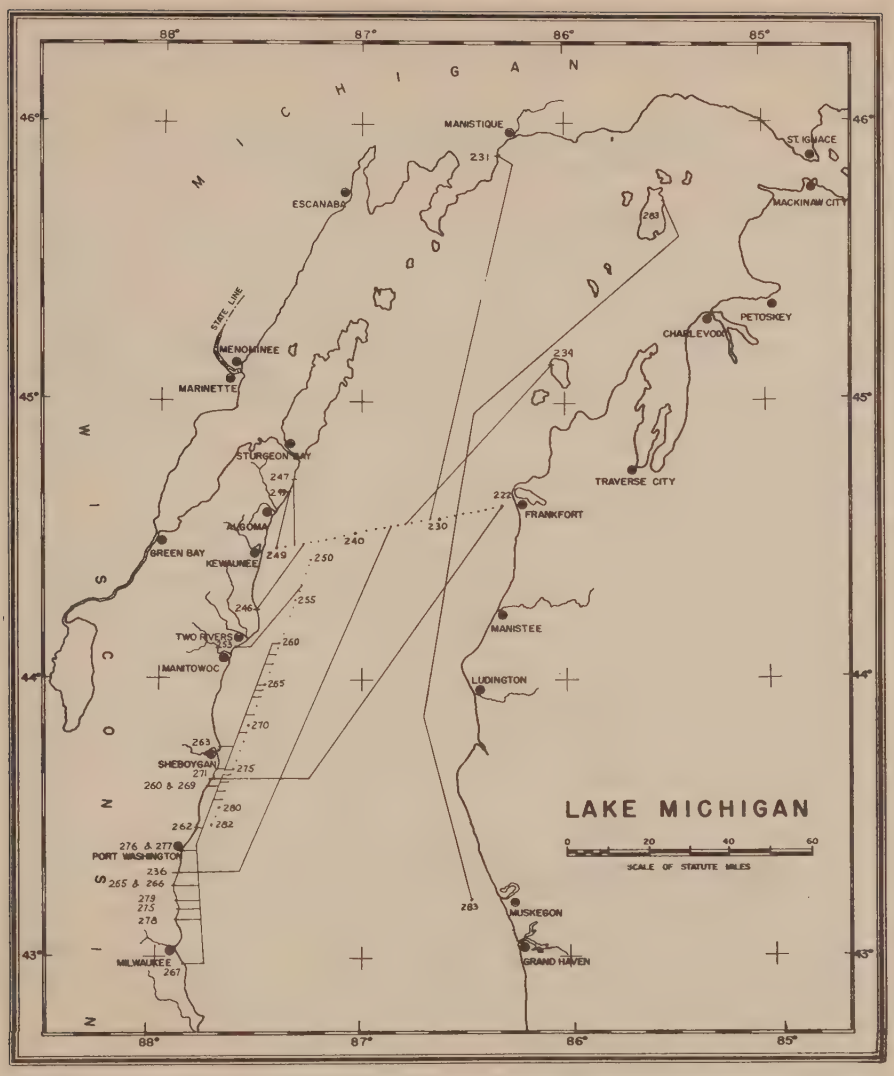



Figure 11.--Movements of bottles released along the transect, Frankfort to Kewaunee, July 30, from Kewaunee to Port Washington, August 12, and off Muskegon, August 17, 1931.

near Thompson, Michigan, and the most southerly one about 7 miles south of Port Washington, Wisconsin.

## Kewaunee to Port Washington

Thirty-three bottles (table 12) were thrown overboard along the Wisconsin shore (fig. 11) on August 12, 1931, and one on August 17 off Muskegon. The last bottle was recovered 320 days later and 190 miles distant at Beaver Island. Fifteen bottles (44 percent) and eight (24 percent) with drags were recovered. During a period of 8-48 days, averaging 15.6, the 14 bottles dropped August 12 had floated minimum distances along Wisconsin from 12-67 miles, averaging 34.4. All of them had floated southwest from about 3 miles south of Two Rivers to Cudahy, Wisconsin.

## Escanaba to Menominee

Twenty-five bottles (table 13) were released in Green Bay from Escanaba to Menominee on May 9, 1932 (fig. 12). Sixteen (64 percent) were discovered along the shore or in the

TABLE 12.--Release and recovery points of drift bottles released in 1931 from Kewaunee, Wisconsin, to Port Washington, Wisconsin (August 12--33 stations), and off Muskegon, Michigan (August 17--1 station).

[Asterisk indicates recovery in year beyond 1931; no. 283 was recovered August 3, 1932]

| Station of release | | | Recoveries | | | | | Drag attached[1] |
|---|---|---|---|---|---|---|---|---|
| Station number | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| August 12 | | | | | | | | |
| 250 | 44° 25.3' | 87° 17.2' | ... | ... | ... | ... | ... | ... |
| 251 | 44° 23.7' | 87° 18.1' | ... | ... | ... | ... | ... | ... |
| 252 | 44° 21.9' | 87° 18.8' | ... | ... | ... | ... | ... | ... |
| 253 | 44° 19.9' | 87° 19.7' | September 27 | 44° 7.2' | 87° 38.1' | 48 | 23 | No |
| 254 | 44° 18.5' | 87° 20.8' | ... | ... | ... | ... | ... | ... |
| 255 | 44° 16.7' | 87° 21.9' | ... | ... | ... | ... | ... | ... |
| 256 | 44° 14.8' | 87° 22.6' | ... | ... | ... | ... | ... | ... |
| 257 | 44° 13.0' | 87° 23.8' | ... | ... | ... | ... | ... | ... |
| 258 | 44° 10.5' | 87° 24.6' | ... | ... | ... | ... | ... | ... |
| 259 | 44° 9.2' | 87° 25.8' | ... | ... | ... | ... | ... | ... |
| 260 | 44° 7.1' | 87° 26.9' | August 24 | 43° 35.8' | 87° 45.4' | 12 | 40 | Yes |
| 261 | 44° 5.5' | 87° 27.2' | ... | ... | ... | ... | ... | ... |
| 262 | 44° 3.6' | 87° 27.7' | August 28 | 43° 27.2' | 87° 48.0' | 16 | 47 | No |
| 263 | 44° 1.9' | 87° 28.2' | August 28 | 43° 45.7' | 87° 42.5' | 16 | 26 | No |
| 264 | 44° 0.0' | 87° 29.7' | ... | ... | ... | ... | ... | ... |
| 265 | 43° 58.2' | 87° 30.6' | August 27 | 43° 14.8' | 87° 55.0' | 15 | 54 | No |
| 266 | 43° 56.7' | 87° 31.8' | August 22 | 43° 14.8' | 87° 55.0' | 10 | 52 | Yes |
| 267 | 43° 54.8' | 87° 32.2' | August 28 | 42° 57.5' | 87° 50.4' | 16 | 67 | Yes |
| 268 | 43° 53.2' | 87° 33.3' | ... | ... | ... | ... | ... | ... |
| 269 | 43° 51.3' | 87° 34.4' | September 2 | 43° 35.2' | 87° 45.9' | 10 | 21 | No |
| 270 | 43° 49.5' | 87° 35.2' | ... | ... | ... | ... | ... | ... |
| 271 | 43° 47.7' | 87° 35.8' | August 22 | 43° 39.9' | 87° 42.6' | 12 | 12 | Yes |
| 272 | 43° 45.8' | 87° 37.1' | ... | ... | ... | ... | ... | ... |
| 273 | 43° 44.0' | 87° 38.3' | ... | ... | ... | ... | ... | ... |
| 274 | 43° 42.3' | 87° 39.0' | ... | ... | ... | ... | ... | ... |
| 275 | 43° 40.0' | 87° 40.3' | August 20 | 43° 10.2' | 87° 52.9' | 8 | 37 | Yes |
| 276 | 43° 38.3' | 87° 41.1' | August 27 | 43° 21.6' | 87° 53.0' | 15 | 22 | No |
| 277 | 43° 36.7' | 87° 42.0' | August 25 | 43° 21.6' | 87° 53.0' | 13 | 20 | Yes |
| 278 | 43° 34.6' | 87° 43.0' | August 21 | 43° 7.8' | 87° 54.1' | 9 | 34 | No |
| 279 | 43° 33.0' | 87° 43.9' | August 21 | 43° 11.5' | 87° 53.7' | 9 | 27 | Yes |
| 280 | 43° 31.2' | 87° 45.2' | ... | ... | ... | ... | ... | ... |
| 281 | 43° 29.0' | 87° 46.0' | ... | ... | ... | ... | ... | ... |
| 282 | 43° 27.5' | 87° 47.1' | ... | ... | ... | ... | ... | ... |
| August 17 | | | | | | | | |
| 283 | 43° 12.1' | 86° 30.0' | August 3* | 45° 42.5' | 85° 29.5' | 320 | 190 | Yes |
| Average | ... | ... | ... | ... | ... | [2] 15.6 | [2] 34.4 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 14 | 14 | ... |

[1] With drags, 8; without drags, 7.
[2] Based on recoveries in year of release.

TABLE 13.--Release and recovery points of drift bottles released May 9, 1932, at 25 stations on an indirect transect, Escanaba, Michigan, to Menominee, Michigan

[ Asterisk indicates recovery in year beyond 1932; no. 285 was recovered on April 22, 1933, and no. 308 on May 10, 1933 ]

| Station of release | | | Recoveries | | | | | |
|---|---|---|---|---|---|---|---|---|
| Station number | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | Drag attached [1] |
| 286 | 45° 42.5' | 87° 2.3' | ... | ... | ... | ... | ... | ... |
| 285 | 45° 41.4' | 87° 2.2' | April 22* | 45° 39.0' | 87° 11.0' | 348 | 7 | No |
| 284 | 45° 39.6' | 87° 1.9' | July 17 | 45° 42.0' | 86° 54.0' | 69 | 8 | Yes |
| 287 | 45° 37.9' | 87° 1.8' | June 3 | 45° 45.0' | 86° 59.0' | 25 | 9 | Yes |
| 288 | 45° 36.2' | 87° 1.7' | ... | ... | ... | ... | ... | ... |
| 289 | 45° 32.7' | 87° 1.5' | ... | ... | ... | ... | ... | ... |
| 290 | 45° 31.7' | 87° 2.5' | June 26 | 44° 59.0' | 87° 38.0' | 48 | 49 | Yes |
| 291 | 45° 29.8' | 87° 3.8' | July 6 | 45° 9.0' | 87° 16.0' | 58 | 25 | No |
| 292 | 45° 28.2' | 87° 4.8' | June 17 | 45° 29.0' | 87° 16.0' | 39 | 9 | ? |
| 293 | 45° 26.6' | 87° 5.7' | June 16 | 45° 13.5' | 87° 31.0' | 38 | 25 | Yes |
| 294 | 45° 24.9' | 87° 7.2' | ... | ... | ... | ... | ... | ... |
| 295 | 45° 23.3' | 87° 8.1' | ... | ... | ... | ... | ... | ... |
| 296 | 45° 21.7' | 87° 9.4' | June 12 | 45° 7.0' | 87° 36.0' | 34 | 28 | Yes |
| 297 | 45° 20.3' | 87° 11.4' | ... | ... | ... | ... | ... | ... |
| 298 | 45° 19.2' | 87° 13.1' | July 4 | 45° 21.0' | 86° 57.0' | 56 | 14 | No |
| 299 | 45° 18.0' | 87° 15.0' | June 21 | 45° 29.0' | 87° 16.0' | 43 | 12 | Yes |
| 302 | 45° 16.7' | 87° 16.7' | June 19 | 45° 21.0' | 87° 24.0' | 41 | 7 | ? |
| 300 | 45° 15.5' | 87° 18.5' | July 9 | 44° 53.5' | 87° 26.5' | 61 | 28 | No |
| 301 | 45° 14.7' | 87° 20.5' | ... | ... | ... | ... | ... | ... |
| 303 | 45° 13.4' | 87° 22.7' | ... | ... | ... | ... | ... | ... |
| 304 | 45° 12.4' | 87° 24.5' | July 19 | 45° 31.0' | 87° 17.0' | 71 | 22 | No |
| 305 | 45° 11.4' | 87° 26.3' | June 8 | 45° 17.5' | 87° 26.0' | 30 | 7 | No |
| 306 | 45° 10.4' | 87° 28.0' | June 24 | 45° 4.5' | 87° 16.5' | 46 | 12 | ? |
| 307 | 45° 88.0' | 87° 30.2' | ... | ... | ... | ... | ... | ... |
| 308 | 45° 7.7' | 87° 32.5' | May 10* | 45° 0.0' | 87° 38.0' | 397 | 11 | No |
| Average | ... | ... | ... | ... | ... | [2] 47.1 | 17.1 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 14 | 16 | ... |

[1] With drags, 6; without drags, 7; no data, 3.
[2] Based on recoveries in year of release.

Figure 12.--Movement of bottles released along the transect, Escanaba to Menominee, May 9, 1932.

water at distances between 7 and 49 miles, an average of 17.1. Ten bottles had floated less than 15 miles. Two of the bottles were found at 348 and 397 days only 7 and 11 miles from release points; the other 14 were recovered between 25 and 71 days, an average of 47.1. Ten bottles landed along the western shore from 7 miles south of Marinette, Wisconsin, to 3 miles south of Ford River, Michigan, and six on the eastern shore of Green Bay from Sherwood Pt. to opposite Escanaba. Six (46 percent) of 13 bottles kept their drags.

## Menominee to Nets and Return

Nineteen bottles (66 percent) were recorded of the 29 (table 14) that were floated on May 17, 1932, off Menominee (fig. 13). Their minimum

TABLE 14.--Release and recovery points of drift bottles released May 17, 1932, at 29 stations from Menominee, Michigan to nets and return

[ Asterisk indicates recovery in years beyond 1932; no. 317 was recovered on October 30, 1933, and no. 329 on October 29, 1933 ]

| Station of release | | | Recoveries | | | | | |
|---|---|---|---|---|---|---|---|---|
| Station number | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | Drag attached [1] |
| 311 | 45° 5.0' | 87° 34.6' | June 16 | 44° 50.5' | 87° 52.5' | 30 | 24 | Yes |
| 309 | 45° 4.2' | 87° 34.2' | June 24 | 45° 8.5' | 87° 36.0' | 38 | 6 | Yes |
| 310 | 45° 3.3' | 87° 33.7' | June 6 | 45° 6.0' | 87° 36.0' | 20 | 4 | Yes |
| 312 | 45° 2.5' | 87° 33.5' | ... | ... | ... | ... | ... | ... |
| 313 | 45° 1.6' | 87° 33.0' | June 5 | 45° 0.0' | 87° 37.5' | 19 | 4 | Yes |
| 314 | 45° 0.5' | 87° 32.7' | ... | ... | ... | ... | ... | ... |
| 315 | 44° 59.6' | 87° 32.2' | June 23 | 44° 38.0' | 88° 0.5' | 37 | 34 | No |
| 316 | 44° 58.8' | 87° 31.9' | May 22 | 45° 3.5' | 87° 30.5' | 5 | 5 | Yes |
| 317 | 44° 58.1' | 87° 31.5' | October 30* | 45° 9.5' | 87° 19.5' | 532 | 16 | Yes |
| 318 | 44° 57.3' | 87° 31.2' | July 11 | 45° 17.5' | 87° 26.2' | 55 | 23 | No |
| 319 | 44° 56.3' | 87° 30.8' | June 14 | 45° 0.0' | 87° 35.5' | 28 | 6 | Yes |
| 320 | 44° 55.4' | 87° 30.2' | ... | ... | ... | ... | ... | ... |
| 321 | 44° 56.0' | 87° 29.7' | July 26 | 44° 47.5' | 87° 55.0' | 70 | 22 | ? |
| 322 | 44° 56.7' | 87° 28.9' | June 12 | 44° 59.0' | 87° 37.5' | 26 | 8 | No |
| 323 | 44° 57.6' | 87° 28.4' | ... | ... | ... | ... | ... | ... |
| 324 | 44° 58.4' | 87° 27.8' | August 5 | 45° 13.0' | 87° 29.0' | 80 | 16 | Yes |
| 325 | 44° 59.5' | 87° 27.3' | ... | ... | ... | ... | ... | ... |
| 326 | 45° 0.3' | 87° 26.8' | July 31 | 44° 59.0' | 87° 37.5' | 75 | 9 | Yes |
| 327 | 45° 3.1' | 87° 22.0' | June 10 | 45° 13.5' | 87° 9.5' | 24 | 16 | Yes |
| 328 | 45° 3.4' | 87° 23.5' | May 25 | 45° 9.0' | 87° 1.9' | 8 | 8 | Yes |
| 329 | 45° 3.8' | 87° 25.0' | October 29* | 45° 12.5' | 87° 20.0' | 531 | 12 | Yes |
| 330 | 45° 4.0' | 87° 26.1' | June 23 | 45° 6.0' | 87° 36.0' | 37 | 9 | Yes |
| 331 | 45° 4.4' | 87° 27.3' | ... | ... | ... | ... | ... | ... |
| 332 | 45° 4.7' | 87° 28.5' | ... | ... | ... | ... | ... | ... |
| 333 | 45° 4.9' | 87° 29.8' | ... | ... | ... | ... | ... | ... |
| 334 | 45° 5.2' | 87° 31.0' | ... | ... | ... | ... | ... | ... |
| 335 | 45° 5.5' | 87° 32.5' | June 20 | 45° 0.0' | 87° 37.5' | 34 | 8 | No |
| 336 | 45° 5.8' | 87° 33.4' | December 20 | 45° 2.0' | 87° 19.5' | 217 | 12 | Yes |
| 337 | 45° 6.0' | 87° 34.8' | ... | ... | ... | ... | ... | ... |
| Average | ... | ... | ... | ... | ... | [2] 36.6 | 12.7 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 16 | 19 | ... |

[1] With drags, 14; without drags, 4; no data, 1.
[2] Excludes 1 bottle recovered in December 1932 and 2 recovered in 1933.

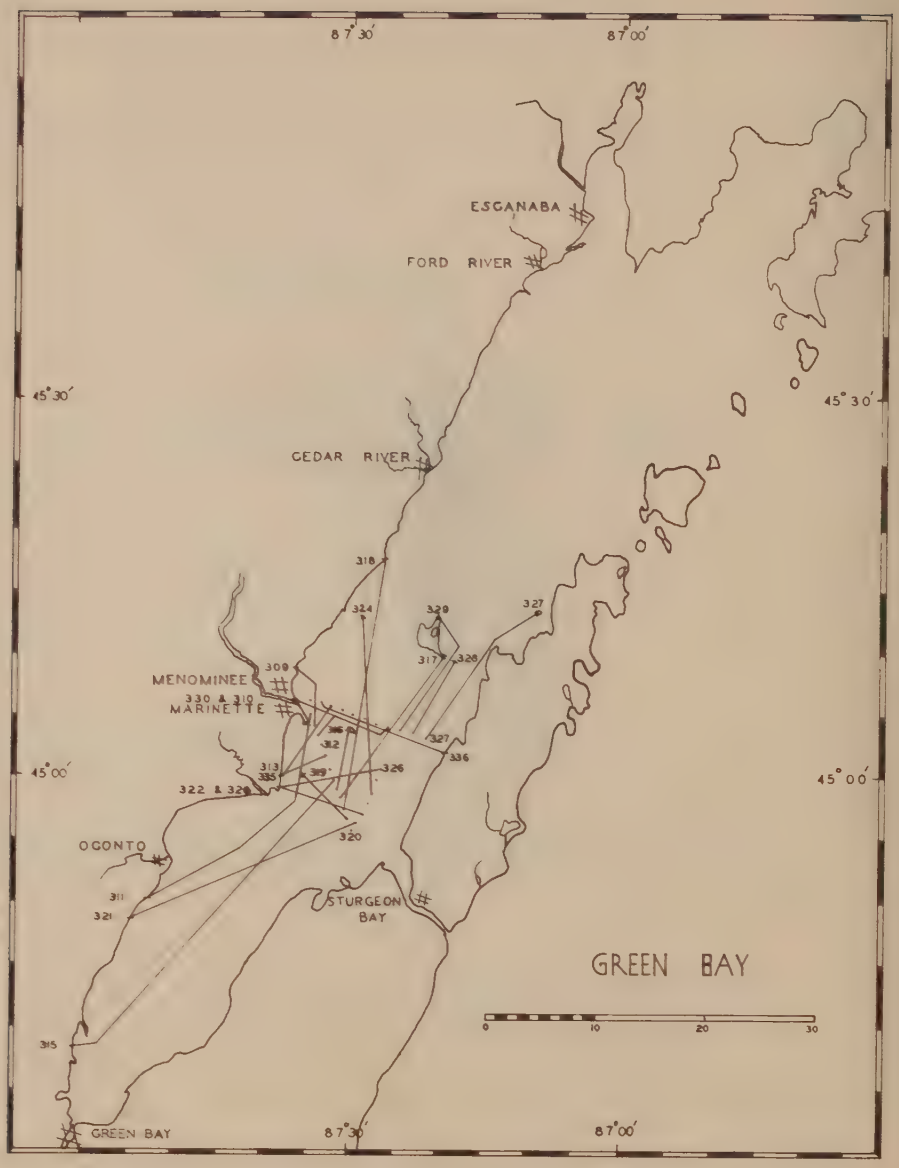



Figure 13.--Movements of bottles released from Menominee to nets and return, May 17, 1932.

miles ranged from 4-34, and averaged 12.7. Three of the bottles were found after 217, 531, and 532 days; the others were collected in 5-80 days, average of 36.6. Two were picked off pound nets and one from a spar buoy. Fourteen bottles (78 percent) retained their drags. It is unusual that the same number of six bottles landed southwest, northwest, and northeast. These different movements demonstrate that the current does not always flow northward in Green Bay. Along the western coast the bottles were found from Suamico, Wisconsin, to Pt. Rochereau and along the eastern shore from Egg Harbor, Wisconsin, to Little Sister Island.

## Two Rivers to Frankfort

Seventy-six bottles (table 15) were released June 2, 1932, along the transect from Two Rivers to Frankfort (fig. 14) and 57 (75 percent) were recovered. Twenty-one (41 percent) of 51 bottles had retained their drags. The bottles were found in 4-113 days (except one, no. 412, that was recovered 437 days after release on August 14, 1933), an average of 43.6, and from 7-120 miles distant, an average of 60.0.

Thirty-nine (68 percent) of the bottles had floated northeastward (5 of them into Traverse Bay), 13 (23 percent) had moved southwestward, and 5 (9 percent) were found to the northwest, southeast, or east. The bottles along the eastern shore had scattered from 2 miles north of Big Point Sable (except one that had floated to 3 miles south of Saugatuck, Michigan), to eastern Cecil Bay. The bottles recovered to the west were distributed from near the Ozaukee-Sheboygan County line to 9 miles north of Two Rivers, Wisconsin.

## Frankfort to Charlevoix

On June 3, 1932, 70 bottles (table 16) were deposited between Frankfort and Charlevoix (fig. 15). Fifty-one (73 percent) were found--all in the State of Michigan. Thirty-two (65 percent) of 49 bottles had their drags attached. Fifty bottles were recovered in 3-130 days averaging 45.4; one bottle was found in 5.75 years, 6 miles south of Cross Village. Minimum distances ranged from 2-93 miles, an average of 33.0, but 47 percent of the bottles were found inside 26 miles and averaged only 13 miles. Nine bottles had floated southward and 42 or 82 percent northward. Eight bottles had entered Grand Traverse Bay. The bottles had been scattered from 1 mile south of Pt. Betsie Light to Sturgeon Bay near Cross Village.

## Charlevoix to Manistique

On June 6, 1932, 54 bottles (table 17) were dropped between Charlevoix and Manistique, Michigan (fig. 16)--35 (65 percent) were recovered and 19 (59 percent) of 32 bottles held their drags. Six bottles were discovered from 0.93-5.8 years after release in 1933, 1934, 1935, and 1938 but had floated an average of only 18.8 miles. The other 29 bottles were recovered in 1-177 days, an average of 54.8, and 22 of these bottles averaged only 35.3 days. All recovered bottles had moved 1-51 miles, average 25.9. Twenty-three bottles were found southeast, 10 northeast, and 2 southwest near Fisherman's Island and Point Detour. The 33 bottles had scattered from northern Antrim County, Grand Traverse Bay, to 1 mile west of Cross Village and to the Gull and Beaver Islands.

## Manistique to Escanaba

Of the 22 bottles (table 18) dropped on June 7, 1932, between Manistique and Escanaba (fig. 17), 16 (73 percent) were collected in 4-516 days and at minimum distances of 6-66 miles, average 26.6. Excluding the 2 bottles discovered beyond 1 year (390 and 516 days), the other 14 bottles were found during an average of 66.3 days (4-173). Drags were noted on six (38 percent) bottles. Only 2 bottles floated eastward; 4 were recovered in northern Green Bay; and 10 drifted southwest as far south as Jacksonport, Wisconsin.

## Manistique to Manistee

Twenty-seven bottles (table 19) were released on June 20, 1932, along the eastern shore of the lake (fig. 17). All of the 20 recoveries (74 percent) were found between Good Harbor Bay and 6 miles south of Manistee. Fourteen floated southeast and six northeast. These bottles were recovered in 4-92 days, an average of 15.6, but 18 bottles had an average of only 10.2 days. The minimum distances covered by the bottles ranged from 5-22 miles, an average of 10.6. Nineteen (95 percent) of the 20 bottles possessed their drags.

## Manistee to Grand Haven

Thirty-nine (95 percent) of the 41 bottles (table 20) released June 21, 1932, between Manistee and Grand Haven (fig. 17) were recovered from the day of release up to 60 days, an average of 10.5, and at 3-26 minimum miles, an average of 10.9. More than half of these bottles had times and distances well

TABLE 15.--Release and recovery points of drift bottles released June 2, 1932, at 76 stations on the transect, Two Rivers, Wisconsin, to Frankfort, Michigan

[Asterisk indicates recovery in year beyond 1932; no. 412 was recovered August 14, 1933]

| Station of release | | | Recoveries | | | | | Drag attached[1] |
|---|---|---|---|---|---|---|---|---|
| Station number | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| 338 | 44° 8.3' | 87° 33.0' | July 11 | 44° 2.0' | 87° 41.0' | 39 | 9 | No |
| 339 | 44° 8.5' | 87° 31.7' | June 9 | 43° 58.0' | 87° 42.0' | 7 | 14 | Yes |
| 340 | 44° 8.9' | 87° 30.4' | June 18 | 43° 58.0' | 87° 42.0' | 16 | 15 | Yes |
| 341 | 44° 9.5' | 87° 29.1' | June 18 | 44° 7.0' | 87° 38.0' | 16 | 7 | Yes |
| 342 | 44° 9.9' | 87° 27.7' | ... | ... | ... | ... | ... | ... |
| 343 | 44° 10.3' | 87° 26.7' | ... | ... | ... | ... | ... | ... |
| 344 | 44° 10.7' | 87° 25.8' | June 15 | 43° 46.0' | 87° 43.0' | 13 | 31 | Yes |
| 345 | 44° 11.2' | 87° 24.7' | ... | ... | ... | ... | ... | ... |
| 346 | 44° 11.5' | 87° 23.3' | June 21 | 44° 17.0' | 87° 32.0' | 19 | 9 | No |
| 347 | 44° 11.9' | 87° 22.2' | June 6 | 44° 13.0' | 86° 29.0' | 4 | 7 | ? |
| 348 | 44° 12.3' | 87° 21.1' | June 12 | 43° 42.0' | 87° 42.0' | 10 | 39 | Yes |
| 349 | 44° 12.7' | 87° 20.0' | June 12 | 43° 42.0' | 87° 42.0' | 10 | 40 | Yes |
| 350 | 44° 13.1' | 87° 18.8' | July 6 | 43° 41.0' | 87° 42.0' | 34 | 42 | No |
| 351 | 44° 13.7' | 87° 17.8' | ... | ... | ... | ... | ... | ... |
| 352 | 44° 14.2' | 87° 16.6' | June 26 | 43° 32.0' | 87° 47.0' | 24 | 54 | No |
| 353 | 44° 14.6' | 87° 15.0' | ... | ... | ... | ... | ... | ... |
| 354 | 44° 15.0' | 87° 13.9' | July 10 | 44° 11.0' | 87° 31.0' | 38 | 14 | Yes |
| 355 | 44° 15.5' | 87° 12.4' | July 5 | 43° 43.0' | 87° 42.0' | 33 | 44 | Yes |
| 356 | 44° 16.0' | 87° 11.5' | June 16 | 43° 45.0' | 87° 42.0' | 14 | 42 | Yes |
| 357 | 44° 16.5' | 87° 10.5' | August 6 | 42° 28.0' | 87° 13.0' | 65 | 120 | No |
| 358 | 44° 16.8' | 87° 9.4' | June 16 | 43° 45.0' | 87° 42.0' | 14 | 44 | Yes |
| 359 | 44° 17.3' | 87° 8.2' | ... | ... | ... | ... | ... | ... |
| 360 | 44° 17.6' | 87° 7.0' | August 3 | 44° 56.0' | 85° 22.0' | 62 | 116 | No |
| 361 | 44° 18.0' | 87° 5.8' | July 28 | 44° 44.0' | 86° 6.0' | 56 | 58 | Yes |
| 362 | 44° 18.4' | 87° 4.6' | August 11 | 44° 44.0' | 86° 6.0' | 70 | 58 | No |
| 363 | 44° 18.8' | 87° 3.3' | July 5 | 44° 37.0' | 86° 14.0' | 33 | 45 | No |
| 364 | 44° 18.8' | 87° 3.3' | July 2 | 45° 6.0' | 85° 20.0' | 30 | 108 | No |
| 365 | 44° 18.8' | 87° 3.3' | July 6 | 44° 5.0' | 86° 30.0' | 34 | 31 | ? |
| 366 | 44° 18.8' | 87° 3.3' | July 8 | 44° 18.0' | 86° 19.0' | 36 | 33 | No |
| 367 | 44° 18.8' | 87° 3.3' | ... | ... | ... | ... | ... | ... |
| 368 | 44° 19.7' | 87° 3.5' | ... | ... | ... | ... | ... | ... |
| 369 | 44° 20.0' | 87° 2.4' | July 29 | 45° 8.0' | 85° 21.0' | 57 | 104 | No |
| 370 | 44° 20.3' | 87° 1.2' | July 22 | 44° 42.0' | 86° 15.0' | 50 | 45 | Yes |
| 371 | 44° 20.7' | 87° 0.0' | July 14 | 44° 55.0' | 86° 3.0' | 42 | 61 | No |
| 372 | 44° 21.0' | 86° 58.8' | September 18 | 45° 7.0' | 86° 4.0' | 108 | 69 | No |
| 373 | 44° 21.4' | 86° 57.8' | ... | ... | ... | ... | ... | ... |
| 374 | 44° 21.8' | 86° 56.7' | July 13 | 44° 29.0' | 86° 15.0' | 41 | 35 | Yes |
| 375 | 44° 22.2' | 86° 55.6' | ... | ... | ... | ... | ... | ... |
| 376 | 44° 22.5' | 86° 54.4' | July 27 | 45° 0.0' | 85° 47.0' | 55 | 71 | No |
| 377 | 44° 22.9' | 86° 53.2' | August 3 | 45° 0.0' | 85° 29.0' | 62 | 102 | No |
| 378 | 44° 23.3' | 86° 52.3' | July 21 | 45° 2.0' | 85° 45.0' | 49 | 70 | No |
| 379 | 44° 24.2' | 86° 50.1' | July 13 | 44° 43.0' | 86° 12.0' | 41 | 38 | Yes |
| 380 | 44° 24.6' | 86° 48.8' | ... | ... | ... | ... | ... | ... |
| 381 | 44° 24.8' | 86° 48.1' | July 16 | 44° 54.0' | 86° 1.0' | 44 | 81 | No |
| 382 | 44° 25.3' | 86° 46.8' | ... | ... | ... | ... | ... | ... |
| 383 | 44° 25.8' | 86° 45.7' | September 7 | 45° 17.0' | 85° 20.0' | 97 | 90 | No |
| 384 | 44° 26.3' | 86° 44.4' | July 16 | 46° 4.0' | 85° 59.0' | 44 | 55 | No |
| 385 | 44° 26.7' | 86° 43.2' | July 23 | 44° 57.0' | 85° 22.0' | 51 | 96 | No |
| 386 | 44° 27.0' | 86° 41.8' | ... | ... | ... | ... | ... | ... |
| 387 | 44° 27.6' | 86° 40.0' | July 21 | 45° 0.0' | 86° 8.0' | 49 | 45 | No |
| 388 | 44° 27.6' | 86° 40.0' | July 24 | 45° 23.0' | 85° 0.0' | 52 | 107 | Yes |
| 389 | 44° 27.6' | 86° 40.0' | ... | ... | ... | ... | ... | ... |
| 390 | 44° 27.6' | 86° 40.0' | July 23 | 45° 22.0' | 85° 0.0' | 51 | 107 | No |
| 391 | 44° 27.6' | 86° 40.0' | July 27 | 45° 22.0' | 85° 6.0' | 55 | 102 | No |

TABLE 15.--Release and recovery--Michigan--Continued

| Station of release | | | Recoveries | | | | | Drag attached[1] |
|---|---|---|---|---|---|---|---|---|
| Station number | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| 392 | 44° 28.0' | 86° 39.1' | July 22 | 45° 23.0' | 84° 55.9' | 50 | 109 | ? |
| 393 | 44° 28.3' | 86° 38.1' | July 11 | 44° 53.0' | 86° 4.0' | 39 | 38 | Yes |
| 394 | 44° 28.7' | 86° 36.9' | July 13 | 45° 0.0' | 85° 47.0' | 41 | 45 | Yes |
| 395 | 44° 29.1' | 86° 35.8' | July 13 | 44° 57.0' | 86° 5.0' | 41 | 32 | No |
| 396 | 44° 29.5' | 86° 34.7' | ... | ... | ... | ... | ... | ... |
| 397 | 44° 30.0' | 86° 33.6' | July 23 | 45° 39.0' | 85° 1.0' | 51 | 105 | Yes |
| 398 | 44° 30.4' | 86° 32.5' | July 30 | 45° 13.0' | 85° 24.0' | 58 | 77 | No |
| 399 | 44° 30.9' | 86° 31.5' | August 19 | 45° 22.0' | 85° 9.0' | 78 | 91 | No |
| 400 | 44° 31.3' | 86° 30.9' | July 9 | 44° 40.0' | 86° 10.0' | 37 | 16 | ? |
| 401 | 44° 31.7' | 86° 30.2' | September 23 | 45° 22.0' | 85° 4.0' | 113 | 95 | No |
| 402 | 44° 32.0' | 86° 29.2' | July 20 | 45° 2.0' | 85° 46.0' | 48 | 50 | No |
| 403 | 44° 32.3' | 86° 28.0' | July 27 | 45° 42.0' | 85° 0.0' | 55 | 107 | ? |
| 404 | 44° 31.8' | 86° 27.1' | July 13 | 45° 0.0' | 86° 9.0' | 41 | 34 | Yes |
| 405 | 44° 33.2' | 86° 26.0' | ... | ... | ... | ... | ... | ... |
| 406 | 44° 33.7' | 86° 25.0' | July 8 | 45° 4.0' | 85° 42.0' | 36 | 51 | Yes |
| 407 | 44° 34.0' | 86° 24.0' | July 3 | 45° 6.0' | 85° 41.0' | 31 | 52 | ? |
| 408 | 44° 34.4' | 86° 22.9' | ... | ... | ... | ... | ... | ... |
| 409 | 44° 34.6' | 86° 21.8' | ... | ... | ... | ... | ... | ... |
| 410 | 44° 35.1' | 86° 20.6' | July 28 | 45° 21.0' | 85° 14.0' | 56 | 77 | No |
| 411 | 44° 35.5' | 86° 19.7' | July 11 | 45° 19.0' | 85° 16.0' | 39 | 73 | Yes |
| 412 | 44° 35.9' | 86° 18.5' | August 14 | 45° 45.0' | 84° 50.0' | 437 | 112 | No |
| 413 | 44° 36.3' | 86° 17.4' | ... | ... | ... | ... | ... | ... |
| Average | ... | ... | ... | ... | ... | [2] 43.6 | 60.9 | ... |
| Number of bottles | ... | ... | ... | .... | ... | 56 | 57 | ... |

[1]With drags, 21; without drags, 30; no data, 6.
[2]Based on recoveries within the year of release

below the averages. It is also unusual that nearly all bottles were located somewhere near or between the above-mentioned ports. The northernmost bottle was found 2 miles north of the Big Sable Point and the southernmost caught in a pound net 4 miles south of Grand Haven. Five bottles moved northeastward, five eastward, and the rest in a southerly direction. Thirty-three (87 percent) of 38 bottles held their drags.

## Grand Haven to Sheboygan

Thirty-eight bottles (table 21) were released June 23, 1932, along this transect (fig. 18), and 27 (71 percent) were recovered. Only seven (26 percent) retained the drag. Not a single bottle was found on the west shore. Sixteen floated southeast and 11 northeast, distributing from 1 mile north of Macatawa, Michigan, to 12 miles south of Frankfort, Michigan. Although all of the bottles, excluding the one found after 335 days, were picked up between 8 and 48 days, averaging 29.7, those released toward Sheboygan were recovered during the later days because of greater distances. For example, the averages of the first 5 bottles dropped near Grand Haven were 12.6 days and 12.8 miles, the central bottles averaged 28.2 days and 35.2 miles, and the last 8 bottles showed 42.9 days and 60.6 miles. The minimum miles ranged from 5-84 and averaged 37.6.

## Sheboygan to Sturgeon Bay

Thirty-three bottles (table 22) were released on June 24, 1932, along the Wisconsin shore (fig. 19). All recovered bottles were found along the eastern coast of the lake except one that was discovered 445 miles distant in Lake St. Clair on June 6, 1942. Eighteen floated northeast (one entering Grand Traverse Bay) and seven moved southeast. The 24 bottles

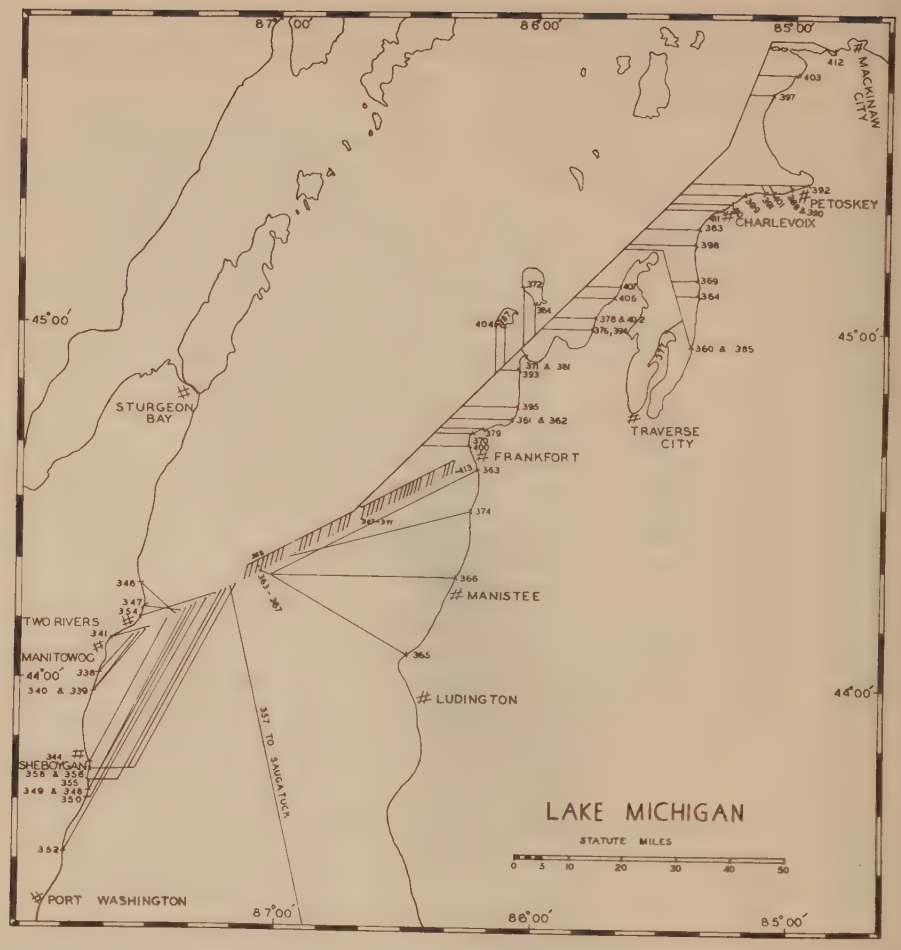



Figure 14.--Movements of bottles released along the transect, Two Rivers to Frankfort, June 2, 1932.

recovered in Lake Michigan were picked up from 1 mile south of the White Lake outlet to Fisherman's Island. These bottles were collected in 29-86 days, an average of 46.4, and at minimum distances of 48-114 miles, averaged 71.7. Only four (16 percent) of the bottles retained their drags.

## Charlevoix to Guiken's Reef

Of the 15 bottles (table 23) released August 9, 1932, along the course from Charlevoix to Guiken's Reef (fig. 20), 8 (53 percent) were found. Six moved toward the south and two toward the north. Two bottles were recovered nearly a year later in July and August 1933; one of them landed on the Lake Michigan shore of the east peninsula of Delta County. The other bottles extended from Glen Arbor, Michigan, to South Fox Island. The bottles were recorded from 8-49 miles, an average of 22.9, and six of them were found in 10-41 days, average of 19.3. Five bottles (62 percent) held their drags.

## Gull Island to Manistique

Seven (58 percent) of the 12 bottles released between Gull Island and Manistique on August 20, 1932 (table 23 and fig. 20) were recovered. All seven floated toward the east, four going northeast and three southeast. Points of recovery extended from Five Mile Creek, north-

TABLE 16.--Release and recovery points of drift bottles released June 3, 1932, at 70 stations between Frankfort, Michigan, and Charlevoix, Michigan

[Asterisk indicates recovery in year beyond 1932; no. 417 was recovered March 1, 1938]

| Station of release | | | Recoveries | | | | | Drag attached[1] |
|---|---|---|---|---|---|---|---|---|
| Station number | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| 414 | 44° 41.3' | 86° 21.4' | August 10 | 45° 40.0' | 85° 0.0' | 68 | 93 | No |
| 415 | 44° 42.2' | 86° 20.5' | July 3 | 45° 4.0' | 85° 42.0' | 30 | 39 | Yes |
| 416 | 44° 43.0' | 86° 19.6' | July 25 | 45° 23.0' | 85° 0.0' | 52 | 80 | No |
| 417 | 44° 43.6' | 86° 19.0' | March 1* | 45° 35.0' | 85° 6.0' | 2,098 | 81 | No |
| 418 | 44° 44.3' | 86° 18.3' | August 2 | 45° 39.0' | 85° 1.0' | 60 | 86 | No |
| 419 | 44° 45.3' | 86° 17.5' | July 31 | 45° 16.0' | 85° 23.0' | 58 | 57 | No |
| 420 | 44° 45.8' | 86° 16.5' | July 8 | 45° 11.0' | 85° 37.0' | 35 | 47 | Yes |
| 421 | 44° 46.4' | 86° 16.0' | July 3 | 45° 5.0' | 85° 42.0' | 30 | 36 | Yes |
| 422 | 44° 47.0' | 86° 15.3' | July 27 | 45° 40.0' | 85° 0.0' | 54 | 85 | ? |
| 423 | 44° 47.7' | 86° 14.6' | ... | ... | ... | ... | ... | ... |
| 424 | 44° 48.4' | 86° 14.0' | July 30 | 45° 19.0' | 85° 16.0' | 57 | 57 | No |
| 425 | 44° 49.1' | 86° 13.0' | ... | ... | ... | ... | ... | ... |
| 426 | 44° 49.8' | 86° 12.5' | ... | ... | ... | ... | ... | ... |
| 427 | 44° 50.4' | 86° 11.4' | ... | ... | ... | ... | ... | ... |
| 428 | 44° 51.3' | 86° 10.7' | September 3 | 45° 40.0' | 85° 10.0' | 92 | 74 | No |
| 429 | 44° 52.0' | 86° 10.0' | ... | ... | ... | ... | ... | ... |
| 430 | 44° 52.5' | 86° 9.3' | ... | ... | ... | ... | ... | ... |
| 431 | 44° 53.0' | 86° 8.5' | ... | ... | ... | ... | ... | ... |
| 432 | 44° 54.1' | 86° 7.7' | June 6 | 44° 58.0' | 85° 55.0' | 3 | 12 | Yes |
| 433 | 44° 54.7' | 86° 7.0' | September 25 | 45° 9.0' | 86° 4.0' | 114 | 16 | No |
| 434 | 44° 55.5' | 86° 6.4' | August 4 | 45° 6.0' | 85° 23.0' | 62 | 47 | Yes |
| 435 | 44° 56.0' | 86° 5.6' | July 22 | 45° 19.0' | 85° 17.0' | 49 | 48 | No |
| 436 | 44° 56.6' | 86° 4.4' | ... | ... | ... | ... | ... | ... |
| 437 | 44° 57.5' | 86° 3.0' | September 9 | 45° 7.0' | 85° 40.0' | 98 | 22 | Yes |
| 438 | 44° 58.2' | 86° 1.9' | July 27 | 45° 13.0' | 85° 24.0' | 54 | 36 | No |
| 439 | 44° 59.0' | 86° 0.5' | July 26 | 45° 10.0' | 85° 24.0' | 53 | 37 | Yes |
| 440 | 45° 0.0' | 85° 58.9' | July 2 | 44° 57.0' | 85° 52.0' | 29 | 6 | Yes |
| 441 | 45° 0.7' | 85° 57.8' | July 8 | 45° 10.0' | 85° 38.0' | 35 | 18 | Yes |
| 442 | 45° 1.6' | 85° 56.7' | ... | ... | ... | ... | ... | ... |
| 443 | 45° 2.3' | 85° 55.5' | June 30 | 45° 8.0' | 85° 23.0' | 27 | 33 | Yes |
| 444 | 45° 2.8' | 85° 54.5' | July 10 | 45° 10.0' | 85° 33.0' | 37 | 36 | Yes |
| 445 | 45° 3.5' | 85° 53.5' | ... | ... | ... | ... | ... | ... |
| 446 | 45° 4.3' | 85° 52.6' | July 24 | 45° 37.0' | 85° 5.0' | 51 | 53 | ? |
| 447 | 45° 4.8' | 85° 51.7' | June 24 | 45° 6.0' | 85° 59.0' | 21 | 7 | No |
| 448 | 45° 5.6' | 85° 50.8' | July 10 | 45° 37.0' | 85° 5.0' | 37 | 51 | Yes |
| 449 | 45° 6.0' | 85° 49.9' | September 10 | 45° 3.0' | 86° 8.0' | 99 | 16 | No |
| 450 | 45° 6.6' | 85° 49.0' | August 17 | 44° 55.0' | 85° 25.0' | 75 | 36 | No |
| 451 | 45° 7.3' | 85° 47.3' | July 21 | 45° 38.0' | 85° 2.0' | 48 | 48 | Yes |
| 452 | 45° 8.5' | 85° 46.2' | July 6 | 45° 28.0' | 85° 5.0' | 33 | 40 | Yes |
| 453 | 45° 8.5' | 85° 46.2' | July 2 | 45° 1.0' | 85° 46.0' | 29 | 5 | Yes |
| 454 | 45° 8.5' | 85° 46.2' | July 3 | 44° 57.0' | 85° 49.0' | 30 | 14 | Yes |
| 455 | 45° 8.5' | 85° 46.2' | ... | ... | ... | ... | ... | ... |
| 456 | 45° 9.4' | 85° 47.2' | June 27 | 44° 41.0' | 86° 16.0' | 24 | 41 | Yes |
| 457 | 45° 10.3' | 85° 46.2' | July 8 | 45° 22.0' | 85° 1.0' | 35 | 39 | Yes |
| 458 | 45° 11.1' | 85° 45.0' | August 12 | 45° 13.0' | 85° 32.0' | 70 | 11 | No |
| 459 | 45° 11.7' | 85° 44.0' | June 28 | 45° 11.0' | 85° 38.0' | 25 | 5 | Yes |
| 460 | 45° 12.3' | 85° 43.0' | ... | ... | ... | ... | ... | ... |
| 461 | 45° 13.0' | 85° 42.0' | July 10 | 45° 24.0' | 85° 51.0' | 37 | 15 | Yes |
| 462 | 45° 13.6' | 85° 41.0' | ... | ... | ... | ... | ... | ... |
| 463 | 45° 14.3' | 85° 40.0' | ... | ... | ... | ... | ... | ... |
| 464 | 45° 15.0' | 85° 39.0' | July 10 | 45° 24.0' | 84° 56.0' | 37 | 36 | Yes |
| 465 | 45° 15.4' | 85° 37.8' | July 10 | 45° 33.0' | 85° 7.0' | 37 | 32 | No |
| 466 | 45° 15.8' | 85° 36.8' | ... | ... | ... | ... | ... | ... |
| 467 | 45° 16.1' | 85° 35.8' | June 26 | 45° 16.0' | 85° 23.0' | 23 | 11 | Yes |
| 468 | 45° 16.3' | 85° 34.8' | June 7 | 45° 23.0' | 84° 55.0' | 4 | 33 | No |

TABLE 16.--Release and recovery...Michigan--Continued

| Station of release | | | Recoveries | | | | | Drag attached [1] |
|---|---|---|---|---|---|---|---|---|
| | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| 469 | 45° 16.4' | 85° 33.5' | June 22 | 45° 17.0' | 85° 22.0' | 20 | 9 | Yes |
| 470 | 45° 16.6' | 85° 32.4' | June 24 | 45° 9.0' | 85° 34.0' | 21 | 13 | Yes |
| 471 | 45° 16.8' | 85° 31.2' | ... | ... | ... | ... | ... | ... |
| 472 | 45° 17.0' | 85° 30.3' | July 28 | 45° 22.0' | 85° 1.0' | 56 | 25 | Yes |
| 473 | 45° 17.3' | 85° 29.5' | July 19 | 45° 19.0' | 85° 18.0' | 46 | 11 | Yes |
| 474 | 45° 17.6' | 85° 28.0' | July 3 | 45° 7.0' | 85° 34.0' | 30 | 14 | Yes |
| 475 | 45° 17.8' | 85° 26.8' | June 19 | 45° 18.0' | 85° 17.0' | 16 | 9 | Yes |
| 476 | 45° 18.1' | 85° 25.5' | October 11 | 45° 21.0' | 85° 13.0' | 130 | 10 | Yes |
| 477 | 45° 18.3' | 85° 24.5' | ... | ... | ... | ... | ... | ... |
| 478 | 45° 18.5' | 85° 23.4' | July 23 | 45° 18.0' | 85° 20.0' | 50 | 3 | No |
| 479 | 45° 18.8' | 85° 22.3' | June 13 | 45° 17.0' | 85° 23.0' | 10 | 2 | Yes |
| 480 | 45° 19.2' | 85° 21.0' | July 10 | 45° 36.0' | 85° 5.0' | 37 | 22 | Yes |
| 481 | 45° 19.4' | 85° 19.5' | July 13 | 45° 39.0' | 85° 1.0' | 40 | 26 | Yes |
| 482 | 45° 19.6' | 85° 17.0' | ... | ... | ... | ... | ... | ... |
| 483 | 45° 19.8' | 85° 16.5' | ... | ... | ... | ... | ... | ... |
| Average | ... | ... | ... | ... | ... | [2] 45.4 | 33.0 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 50 | 51 | ... |

[1] With drags, 32; without drags, 17; no data, 2.
[2] Based on recoveries in year of release.

west of Harbor Springs, Michigan, to the west side of Epoufette Point. Three bottles were recovered at 256 and 313 days at 1933 and 3.2 years in 1935; the other four were found at 15-44 days, averaging 26.2. The seven bottles had floated from 7-64 miles, an average of 41.4. Only two bottles held their drags.

## Charlevoix to Dahlia Shoal and Northwest of Charlevoix

All recovered bottles (table 24 and fig. 21) from releases of August 23, 1932, floated northeast and all but one of those reported from the August 25, 1932, releases moved southeast. The former extended from about 3 miles south of Good Hart, Micigan, to Waugoshance Island and the latter from 2 miles north of Charlevoix to halfway between Good Hart and Cross Village, Michigan. Six (46 percent) of the first 13 (table 24) and 5 (71 percent) of the other 7 bottles were recovered, but 4 were found from April 16 to May 4, 1933-236-252 days. The rest of them were located in 5-16 days, averaging 9.0, and 24-73 days, averaging 42.0. Their minimum miles varied from 4-24, averaging 14.8 and from 12-22, averaging 16.0. Three (50 and 60 percent) of bottles recovered from each release held drags.

## GENERAL CHARACTERISTICS

Most of the bottles released in 1931 along transects were recovered along the eastern shore. On only two dates were the small majorities found on the western coast. Eighty-three transect bottles or 65.9 percent were found in the State of Michigan, 31 bottles or 24.6 percent in Wisconsin and Illinois, and 12 bottles or 9.5 percent in Indiana. Other bottles were deposited along both shores. Sixteen of the 17 bottles recovered from releases between St. Joseph and Grand Haven and 21 of the 29 bottles returned from releases between Sheboygan and Racine were found on the eastern coast; the remaining 9 were found along the western shore. All 14 recovered bottles from the Kewaunee-Port Washington releases were discovered in Wisconsin. Of the entire total of recovered bottles, 120 (64.5 percent) were located in the State of Michigan, 54 (29.0 percent) in Wisconsin and Illinois, and 12 (6.5 percent) in Indiana.

Figure 15.--Movements of bottles released from Frankfort to Charlevoix, June 3, 1932.

Table 17. --Release and recovery points of drift bottles released June 6, 1932, at 54 stations on the transect, Charlevoix, Michigan, to Manistique, Michigan

[Asterisk indicates recovery in years beyond 1932; no. 487 was recovered on July 9, 1933, no. 515 on March 27, 1938, no. 520 on May 10, 1933, no. 522 on June 5, 1933, no. 526 on August 30, 1933, and no. 527 on Oct. 5, 1934]

| Stations of release | | | Recoveries | | | | | Drag attached [1] |
|---|---|---|---|---|---|---|---|---|
| Station number | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| 484 | 45° 19.8' | 85° 16.5' | June 10 | 45° 19.0' | 85° 16.0' | 4 | 1 | Yes |
| 485 | 45° 20.3' | 85° 17.8' | June 7 | 45° 18.0' | 85° 22.0' | 1 | 3 | Yes |
| 486 | 45° 20.7' | 85° 19.1' | ... | ... | ... | ... | ... | ... |
| 487 | 45° 21.2' | 85° 20.5' | July 9* | 45° 19.0' | 85° 16.0' | 398 | 4 | No |
| 488 | 45° 21.8' | 85° 21.7' | ... | ... | ... | ... | ... | ... |
| 489 | 45° 22.4' | 85° 23.0' | August 25 | 45° 35.0' | 85° 7.0' | 80 | 21 | Yes |
| 490 | 45° 22.8' | 85° 24.2' | ... | ... | ... | ... | ... | ... |
| 491 | 45° 23.2' | 85° 25.4' | July 14 | 45° 37.0' | 85° 5.0' | 38 | 23 | Yes |
| 492 | 45° 23.7' | 85° 26.5' | July 3 | 45° 22.0' | 85° 0.0' | 27 | 22 | Yes |
| 493 | 45° 24.2' | 85° 27.6' | July 10 | 45° 19.0' | 85° 19.0' | 34 | 10 | Yes |
| 494 | 45° 24.5' | 85° 28.8' | July 15 | 45° 37.0' | 85° 7.0' | 39 | 24 | Yes |
| 495 | 45° 25.0' | 85° 30.1' | July 12 | 45° 19.0' | 85° 19.0' | 36 | 12 | Yes |
| 496 | 45° 25.4' | 85° 31.1' | ... | ... | ... | ... | ... | ... |
| 497 | 45° 25.8' | 85° 32.2' | ... | ... | ... | ... | ... | ... |
| 498 | 45° 26.3' | 85° 33.3' | November 8 | 45° 35.0' | 85° 7.0' | 155 | 24 | Yes |
| 499 | 45° 26.7' | 85° 34.5' | July 7 | 45° 22.0' | 85° 0.0' | 31 | 28 | Yes |
| 500 | 45° 27.2' | 85° 35.7' | August 3 | 45° 22.0' | 85° 3.0' | 58 | 26 | No |
| 502 | 45° 27.7' | 85° 36.9' | July 14 | 45° 22.0' | 85° 0.0' | 38 | 30 | ? |
| 503 | 45° 28.0' | 85° 38.0' | July 20 | 45° 22.0' | 85° 0.0' | 44 | 31 | Yes |
| 504 | 45° 28.4' | 85° 39.2' | July 3 | 45° 13.0' | 85° 33.0' | 27 | 18 | Yes |
| 501 | 45° 28.9' | 85° 40.3' | August 28 | 45° 22.0' | 85° 0.0' | 83 | 33 | Yes |
| 505 | 45° 29.3' | 85° 41.5' | July 14 | 45° 22.0' | 85° 0.0' | 38 | 34 | ? |
| 506 | 45° 29.7' | 85° 42.7' | October 9 | 45° 11.0' | 85° 23.0' | 125 | 27 | No |
| 507 | 45° 30.0' | 85° 43.7' | ... | ... | ... | ... | ... | ... |
| 508 | 45° 30.5' | 85° 44.9' | ... | ... | ... | ... | ... | ... |
| 509 | 45° 31.0' | 85° 46.0' | July 9 | 45° 22.0' | 85° 3.0' | 33 | 35 | Yes |
| 510 | 45° 31.4' | 85° 47.0' | October 1 | 45° 21.0' | 85° 14.0' | 117 | 29 | Yes |
| 511 | 45° 31.8' | 85° 48.0' | ... | ... | ... | ... | ... | ... |
| 512 | 45° 32.1' | 85° 49.0' | August 4 | 45° 22.0' | 85° 0.0' | 59 | 41 | No |
| 513 | 45° 32.7' | 85° 50.1' | July 18 | 45° 22.0' | 85° 0.0' | 42 | 42 | Yes |
| 514 | 45° 33.0' | 85° 51.2' | ... | ... | ... | ... | ... | ... |
| 515 | 45° 33.5' | 85° 52.4' | March 27* | 45° 37.0' | 85° 37.0' | 2,120 | 13 | No |
| 516 | 45° 33.9' | 85° 53.5' | ... | ... | ... | ... | ... | ... |
| 517 | 45° 34.4' | 85° 54.6' | ... | ... | ... | ... | ... | ... |
| 518 | 45° 34.8' | 85° 55.8' | July 19 | 45° 38.0' | 85° 4.0' | 43 | 42 | Yes |
| 519 | 45° 35.2' | 85° 57.0' | November 30 | 45° 37.0' | 85° 37.0' | 177 | 16 | No |
| 520 | 45° 35.8' | 85° 58.1' | May 10* | 45° 42.0' | 85° 50.0' | 338 | 9 | Yes |
| 521 | 45° 33.3' | 86° 3.0' | August 21 | 45° 27.0' | 85° 3.0' | 76 | 47 | No |
| 522 | 45° 33.3' | 86° 3.0' | June 5* | 45° 29.0' | 85° 47.0' | 1,094 | 13 | ? |
| 523 | 45° 33.3' | 86° 3.0' | ... | ... | ... | ... | ... | ... |
| 524 | 45° 35.2' | 85° 59.8' | ... | ... | ... | ... | ... | ... |
| 525 | 45° 36.8' | 86° 0.7' | July 22 | 45° 35.0' | 85° 35.0' | 46 | 21 | No |
| 526 | 45° 38.2' | 86° 2.0' | August 30* | 45° 45.0' | 85° 33.0' | 450 | 25 | No |
| 527 | 45° 39.8' | 86° 3.0' | October 5* | 45° 27.0' | 85° 3.0' | 851 | 49 | No |
| 528 | 45° 41.2' | 86° 3.8' | July 13 | 45° 28.0' | 85° 5.0' | 37 | 49 | No |
| 529 | 45° 42.7' | 86° 4.8' | July 17 | 45° 38.0' | 85° 4.0' | 41 | 51 | No |
| 530 | 45° 44.1' | 86° 5.9' | ... | ... | ... | ... | ... | ... |
| 531 | 45° 45.6' | 86° 6.9' | July 25 | 45° 24.0' | 85° 51.0' | 49 | 28 | No |
| 532 | 45° 47.1' | 86° 7.8' | ... | ... | ... | ... | ... | ... |
| 533 | 45° 48.6' | 86° 9.0' | June 18 | 45° 37.0' | 86° 37.0' | 12 | 26 | Yes |
| 534 | 45° 50.2' | 86° 10.0' | ... | ... | ... | ... | ... | ... |
| 535 | 45° 51.6' | 86° 11.0' | ... | ... | ... | ... | ... | ... |
| 536 | 45° 53.0' | 86° 12.1' | ... | ... | ... | ... | ... | ... |
| 537 | 45° 54.4' | 86° 13.1' | ... | .... | ... | ... | ... | ... |
| Average | ... | ... | ... | ... | ... | [2] 54.8 | 25.9 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 29 | 35 | ... |

[1] With drags, 19; without drags, 13; no data, 3.
[2] Based on recoveries in year of release.

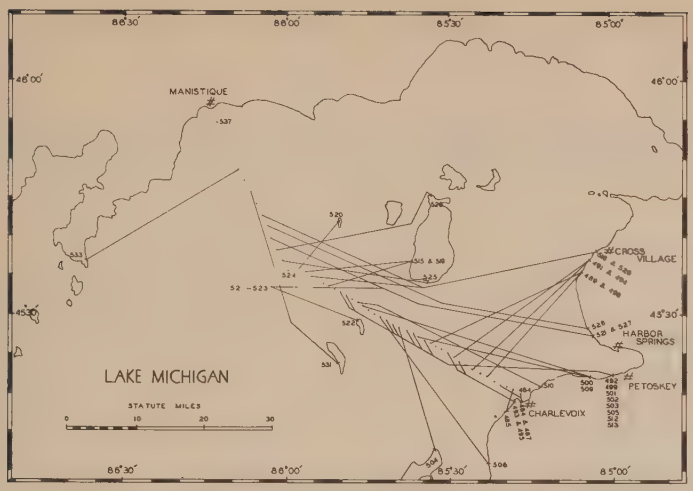



Figure 16.--Movements of bottles released along the transect, Charlevoix to Manistique, June 6, 1932.

Figure 17.--Movements of bottles released from Manistique to Escanaba, June 7, from Manistique to Manistee, June 20, and from Manistee to Grand Haven, June 21, 1932.

TABLE 18. --Release and recovery points of drift bottles released June 7, 1932, at 22 stations from Manistique, Michigan to Escanaba, Michigan, via Poverty Island

[Asterisk indicates recovery in years beyond 1932; no. 538 was recovered on July 2, 1933, and no. 546 on November 5, 1933]

| Station of release | | | Recoveries | | | | | Drag attached [1] |
|---|---|---|---|---|---|---|---|---|
| Station number | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| 538 | 45° 46.6' | 86° 18.1' | July 2* | 45° 31.0' | 86° 43.0' | 390 | 30 | No |
| 539 | 45° 45.1' | 86° 19.6' | ... | ... | ... | ... | ... | ... |
| 540 | 45° 43.8' | 86° 21.7' | ... | ... | ... | ... | ... | ... |
| 541 | 45° 42.4' | 86° 23.2' | November 27 | 45° 45.0' | 85° 42.0' | 173 | 34 | Yes |
| 542 | 45° 41.7' | 86° 25.2' | July 19 | 45° 18.0' | 86° 57.0' | 42 | 40 | Yes |
| 543 | 45° 40.5' | 86° 27.0' | August 1 | 45° 30.0' | 86° 46.0' | 55 | 34 | Yes |
| 544 | 45° 39.0' | 86° 29.0' | ... | ... | ... | ... | ... | ... |
| 545 | 45° 37.6' | 86° 30.1' | ... | ... | ... | ... | ... | ... |
| 546 | 45° 36.0' | 86° 32.0' | November 5* | 45° 25.0' | 86° 50.0' | 516 | 22 | No |
| 547 | 45° 34.7' | 86° 33.5' | August 3 | 45° 20.0' | 85° 15.0' | 57 | 66 | No |
| 548 | 45° 33.2' | 86° 35.3' | ... | ... | ... | ... | ... | ... |
| 549 | 45° 31.3' | 86° 37.6' | ... | ... | ... | ... | ... | ... |
| 550 | 45° 30.0' | 86° 39 5' | October 6 | 45° 22.0' | 86° 57.0' | 121 | 18 | No |
| 551 | 45° 31.3' | 86° 42.0' | September 17 | 45° 40.0' | 86° 58.0' | 102 | 16 | Yes |
| 552 | 45° 32.5' | 86° 43.5' | September 19 | 45° 42.0' | 86° 40.0' | 104 | 11 | No |
| 554 | 45° 33.2' | 86° 46.2' | June 15 | 45° 38.0' | 86° 59.0' | 8 | 11 | Yes |
| 553 | 45° 33.8' | 86° 48.5' | August 17 | 45° 3.0' | 87° 5.0' | 71 | 41 | No |
| 555 | 45° 34.2' | 86° 51.0' | July 1 | 45° 25.0' | 86° 54.0' | 24 | 13 | No |
| 556 | 45° 34.8' | 86° 53.6' | July 5 | 45° 0.0' | 87° 10.0' | 28 | 42 | No |
| 557 | 45° 35.4' | 86° 55.9' | June 11 | 45° 33.0' | 87° 13.0' | 4 | 13 | Yes |
| 558 | 45° 35.9' | 86° 58.0' | August 3 | 45° 20.0' | 87° 25.0' | 57 | 28 | No |
| 559 | 45° 36.5' | 87° 0.1' | August 28 | 45° 39.0' | 87° 9.0' | 82 | 6 | No |
| 560 | [2] ... | [2] ... | ... | ... | ... | ... | ... | ... |
| Average | ... | ... | ... | ... | ... | [3] 66.3 | 26.6 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 14 | 16 | ... |

[1] With drags, 6; without drags, 10.
[2] Bottle kept for sample.
Based on recoveries in year of release.

TABLE 19. --Release and recovery points of drift bottles released June 20, 1932, at 27 stations between Manistique, Michigan, and Manistee, Michigan

| Station of release | | | Recoveries | | | | | Drag attached [1] |
|---|---|---|---|---|---|---|---|---|
| Station number | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| 561 | 45° 2.8' | 86° 16.1' | July 2 | 44° 54.0' | 85° 58.0' | 12 | 19 | Yes |
| 562 | 45° 1.1' | 86° 16.2' | September 20 | 45° 0.0' | 86° 9.0' | 92 | 7 | Yes |
| 563 | 44° 59.3' | 86° 16.4' | ... | ... | ... | ... | ... | ... |
| 564 | 44° 57.5' | 86° 16.6' | ... | ... | ... | ... | ... | ... |
| 565 | 44° 55.8' | 86° 16.9' | July 4 | 44° 56.0' | 85° 50.0' | 14 | 22 | Yes |
| 566 | 44° 54.1' | 86° 17.2' | July 2 | 44° 44.0' | 86° 7.0' | 12 | 16 | Yes |
| 567 | 44° 52.3' | 86° 17.5' | ... | ... | ... | ... | ... | ... |
| 568 | 44° 50.5' | 86° 17.7' | ... | ... | ... | ... | ... | ... |
| 569 | 44° 48.8' | 86° 17.8' | July 2 | 44° 44.0' | 86° 7.0' | 12 | 12 | Yes |
| 570 | 44° 47.1' | 86° 18.0' | July 3 | 44° 43.0' | 86° 12.0' | 13 | 9 | Yes |
| 571 | 44° 45.3' | 86° 18.2' | June 28 | 44° 40.0' | 86° 16.0' | 8 | 8 | Yes |
| 572 | 44° 43.2' | 86° 18.6' | July 25 | 44° 37.0' | 86° 13.0' | 35 | 9 | Yes |
| 573 | 44° 41.7' | 86° 18.8' | July 1 | 44° 38.0' | 86° 16.0' | 11 | 6 | Yes |
| 574 | 44° 40.0' | 86° 19.0' | July 2 | 44° 44.0' | 86° 7.0' | 12 | 11 | Yes |
| 575 | 44° 37.4' | 86° 19.2' | June 29 | 44° 29.0' | 86° 15.0' | 9 | 11 | Yes |
| 576 | 44° 36.6' | 86° 19.5' | June 26 | 44° 33.0' | 86° 14.0' | 6 | 6 | Yes |
| 577 | 44° 34.7' | 86° 19.7' | June 27 | 44° 22.0' | 86° 16.0' | 7 | 16 | Yes |
| 578 | 44° 33.0' | 86° 19.9' | July 10 | 44° 31.0' | 86° 15.0' | 20 | 6 | Yes |
| 579 | 44° 31.2' | 86° 20.0' | July 2 | 44° 32.0' | 86° 14.0' | 12 | 6 | Yes |
| 580 | 44° 29.4' | 86° 20.2' | ... | ... | ... | ... | ... | ... |
| 581 | 44° 27.7' | 86° 20.5' | June 27 | 44° 15.0' | 86° 21.0' | 7 | 17 | Yes |
| 582 | 44° 25.9' | 86° 20.8' | July 5 | 44° 34.0' | 86° 14.0' | 15 | 10 | No |
| 583 | 44° 24.4' | 86° 21.0' | ... | ... | ... | ... | ... | ... |
| 584 | 44° 22.3' | 86° 21.2' | June 24 | 44° 19.0' | 86° 17.0' | 4 | 6 | Yes |
| 585 | 44° 21.0' | 86° 21.5' | ... | ... | ... | ... | ... | ... |
| 586 | 44° 19.3' | 86° 21.7' | June 25 | 44° 10.0' | 86° 24.0' | 5 | 10 | Yes |
| 587 | 44° 17.6' | 86° 22.0' | June 25 | 44° 19.0' | 86° 17.0' | 5 | 5 | Yes |
| Average | ... | ... | ... | ... | ... | 15.6 | 10.6 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 20 | 20 | ... |

[1] With drags, 19; without drags, 1.

Table 20. --Release and recovery points of drift bottles released June 21, 1932, at 41 stations from Manistee, Michigan, to Grand Haven, Michigan

| Station of release | | | Recoveries | | | | | Drag attached [1] |
|---|---|---|---|---|---|---|---|---|
| Station number | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| 588 | 44° 13.6' | 86° 22.8' | August 7 | 44° 5.0' | 86° 30.0' | 47 | 10 | Yes |
| 589 | 44° 12.4' | 86° 24.5' | June 29 | 44° 1.0' | 86° 31.0' | 8 | 14 | Yes |
| 590 | 44° 10.9' | 86° 26.3' | June 27 | 44° 4.0' | 86° 32.0' | 6 | 9 | Yes |
| 591 | 44° 9.5' | 86° 27.8' | ... | ... | ... | ... | ... | ... |
| 592 | 44° 8.1' | 86° 29.7' | June 28 | 43° 58.0' | 86° 28.0' | 7 | 12 | Yes |
| 593 | 44° 6.8' | 86° 31.2' | August 10 | 44° 4.0' | 86° 32.0' | 50 | 4 | Yes |
| 594 | 44° 5.3' | 86° 33.1' | June 29 | 43° 58.0' | 86° 28.0' | 8 | 9 | Yes |
| 595 | 44° 3.6' | 86° 33.8' | July 5 | 43° 42.0' | 86° 31.0' | 14 | 22 | No |
| 596 | 44° 1.8' | 86° 34.0' | July 4 | 44° 3.0' | 86° 31.0' | 13 | 4 | ? |
| 597 | 44° 0.0' | 86° 34.0' | June 25 | 43° 52.0' | 86° 26.0' | 4 | 11 | Yes |
| 598 | 43° 58.4' | 86° 34.0' | July 1 | 43° 46.0' | 86° 27.0' | 10 | 16 | Yes |
| 599 | 43° 56.6' | 86° 34.2' | July 1 | 43° 34.0' | 86° 31.0' | 10 | 26 | Yes |
| 600 | 43° 54.8' | 86° 34.3' | June 30 | 43° 42.0' | 86° 31.0' | 9 | 15 | Yes |
| 601 | 43° 53.0' | 86° 34.4' | ... | ... | ... | ... | ... | ... |
| 602 | 43° 51.0' | 86° 34.5' | July 1 | 43° 37.0' | 86° 32.0' | 10 | 16 | Yes |
| 603 | 43° 49.2' | 86° 34.6' | July 4 | 43° 28.0' | 86° 28.0' | 13 | 25 | Yes |
| 604 | 43° 47.5' | 86° 34.7' | July 11 | 43° 32.0' | 86° 29.0' | 20 | 18 | Yes |
| 605 | 43° 46.5' | 86° 34.8' | June 29 | 43° 33.0' | 86° 30.0' | 8 | 16 | No |
| 606 | 43° 43.6' | 86° 34.9' | June 26 | 43° 33.0' | 86° 30.0' | 5 | 14 | Yes |
| 607 | 43° 41.9' | 86° 35.0' | June 22 | 43° 42.0' | 86° 31.0' | 1 | 5 | Yes |
| 608 | 43° 40.0' | 86° 35.1' | July 1 | 43° 40.0' | 86° 33.0' | 10 | 3 | Yes |
| 609 | 43° 38.0' | 86° 35.0' | June 23 | 43° 42.0' | 86° 31.0' | 2 | 7 | Yes |
| 610 | 43° 36.5' | 86° 34.8' | June 24 | 43° 37.0' | 86° 32.0' | 3 | 3 | Yes |
| 611 | 43° 34.5' | 86° 34.5' | July 1 | 43° 35.0' | 86° 31.0' | 10 | 3 | Yes |
| 612 | 43° 32.8' | 86° 34.1' | June 22 | 43° 33.0' | 86° 30.0' | 1 | 3 | Yes |
| 613 | 43° 31.0' | 86° 33.8' | June 26 | 43° 17.0' | 86° 23.0' | 5 | 19 | Yes |
| 614 | 43° 29.2' | 86° 33.5' | June 25 | 43° 28.0' | 86° 28.0' | 4 | 5 | No |
| 615 | 43° 27.5' | 86° 33.2' | June 22 | 43° 26.0' | 86° 27.0' | 1 | 6 | Yes |
| 616 | 43° 25.9' | 86° 33.0' | June 25 | 43° 23.0' | 86° 26.0' | 4 | 7 | Yes |
| 617 | 43° 24.2' | 86° 32.8' | June 22 | 43° 23.0' | 86° 26.0' | 1 | 6 | Yes |
| 618 | 43° 22.3' | 86° 32.6' | June 26 | 43° 12.0' | 86° 18.0' | 5 | 16 | Yes |
| 619 | 43° 20.7' | 86° 31.2' | June 25 | 43° 4.0' | 86° 16.0' | 4 | 22 | Yes |
| 620 | 43° 19.1' | 86° 30.0' | June 21 | 43° 16.0' | 86° 22.0' | 0 | 7 | Yes |
| 621 | 43° 17.4' | 86° 29.0' | June 29 | 43° 11.0' | 86° 18.0' | 8 | 11 | No |
| 622 | 43° 16.7' | 86° 28.0' | July 2 | 43° 4.0' | 86° 16.0' | 11 | 17 | Yes |
| 623 | 43° 14.2' | 86° 26.5' | June 28 | 43° 16.0' | 86° 22.0' | 7 | 4 | No |
| 624 | 43° 12.6' | 86° 25.7' | July 2 | 43° 0.0' | 86° 17.0' | 11 | 17 | Yes |
| 625 | 43° 10.7' | 86° 24.2' | July 9 | 43° 11.0' | 86° 18.0' | 18 | 5 | Yes |
| 626 | 43° 9.0' | 86° 23.3' | June 22 | 43° 8.0' | 86° 17.0' | 1 | 6 | Yes |
| 627 | 43° 7.4' | 86° 22.0' | June 23 | 43° 8.0' | 86° 17.0' | 2 | 5 | Yes |
| 628 | 43° 5.7' | 86° 20.9' | August 20 | 43° 4.0' | 86° 16.0' | 60 | 6 | Yes |
| Average | ... | ... | ... | ... | ... | 10.5 | 10.9 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 39 | 39 | ... |

[1] With drags, 33; without drags, 5; no data, 1.

Table 21.--Release and recovery points of drift bottles released June 23, 1932, at 38 stations on the transect, Grand Haven, Michigan, to Sheboygan, Michigan

[Asterisk indicates recovery in years beyond 1932; no. 632 was recovered on May 24, 1933]

| Station of release | | | Recoveries | | | | | Drag attached [1] |
|---|---|---|---|---|---|---|---|---|
| Station number | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| 629 | 43° 5.1' | 86° 20.5' | July 8 | 42° 58.0' | 86° 13.0' | 15 | 11 | No |
| 630 | 43° 6.2' | 86° 23.0' | July 1 | 43° 9.0' | 86° 17.0' | 8 | 5 | Yes |
| 631 | 43° 7.3' | 86° 25.0' | July 3 | 43° 5.0' | 86° 15.0' | 10 | 7 | Yes |
| 632 | 43° 8.4' | 86° 27.0' | May 24* | 43° 12.0' | 86° 18.0' | 335 | 7 | No |
| 633 | 43° 9.5' | 86° 29.0' | ... | ... | ... | ... | ... | ... |
| 634 | 43° 10.6' | 86° 31.1' | July 8 | 42° 47.0' | 86° 12.0' | 15 | 30 | Yes |
| 635 | 43° 11.7' | 86° 33.2' | July 8 | 43° 12.0' | 86° 18.0' | 15 | 11 | No |
| 636 | 43° 12.5' | 86° 35.4' | ... | ... | ... | ... | ... | ... |
| 637 | 43° 13.5' | 86° 37.7' | ... | ... | .... | ... | ... | ... |
| 638 | 43° 14.6' | 86° 39.8' | ... | ... | ... | ... | ... | ... |
| 639 | 43° 15.7' | 86° 42.1' | ... | ... | ... | ... | ... | ... |
| 640 | 43° 16.7' | 86° 44.3' | July 24 | 42° 58.0' | 86° 13.0' | 31 | 35 | No |
| 641 | 43° 17.7' | 86° 46.4' | July 20 | 43° 21.0' | 86° 25.0' | 27 | 18 | No |
| 642 | 43° 18.8' | 86° 48.5' | July 20 | 43° 15.0' | 86° 21.0' | 27 | 23 | No |
| 643 | 43° 19.8' | 86° 50.8' | July 22 | 43° 19.0' | 86° 24.0' | 29 | 22 | No |
| 644 | 43° 20.9' | 86° 52.9' | July 20 | 43° 2.0' | 86° 14.0' | 27 | 39 | No |
| 645 | 43° 22.0' | 86° 55.1' | ... | ... | ... | ... | ... | ... |
| 646 | 43° 23.1' | 86° 56.0' | July 24 | 43° 55.0' | 86° 26.0' | 31 | 46 | No |
| 647 | 43° 24.2' | 86° 57.2' | July 18 | 43° 40.0' | 86° 32.0' | 25 | 29 | No |
| 648 | 43° 25.0' | 86° 59.5' | July 21 | 43° 26.0' | 86° 27.0' | 28 | 27 | No |
| 649 | 43° 26.1' | 87° 1.6' | July 26 | 43° 15.0' | 86° 21.0' | 33 | 36 | No |
| 650 | 43° 27.2' | 87° 4.0' | July 20 | 44° 3.0' | 86° 31.0' | 27 | 51 | No |
| 651 | 43° 28.2' | 87° 6.1' | July 20 | 43° 22.0' | 86° 25.0' | 27 | 36 | No |
| 652 | 43° 29.2' | 87° 8.1' | July 20 | 44° 3.0' | 86° 31.0' | 27 | 51 | No |
| 653 | 43° 30.0' | 87° 10.2' | July 21 | 43° 14.0' | 86° 21.0' | 28 | 45 | No |
| 654 | 43° 31.3' | 87° 12.5' | ... | ... | ... | ... | ... | ... |
| 655 | 43° 32.2' | 87° 14.8' | August 10 | 44° 5.0' | 86° 30.0' | 48 | 67 | Yes |
| 656 | 43° 33.2' | 87° 17.0' | July 20 | 43° 14.0' | 86° 21.0' | 27 | 53 | No |
| 657 | 43° 34.3' | 87° 19.0' | August 15 | 43° 12.0' | 86° 18.0' | 43 | 58 | No |
| 658 | 43° 35.4' | 87° 21.3' | ... | ... | ... | ... | ... | ... |
| 659 | 43° 36.4' | 87° 23.5' | ... | ... | ... | ... | ... | ... |
| 660 | 43° 37.3' | 87° 25.0' | August 5 | 43° 33.0' | 86° 30.0' | 43 | 47 | No |
| 661 | 43° 38.4' | 87° 26.5' | August 5 | 43° 14.0' | 86° 21.0' | 43 | 62 | No |
| 662 | 43° 39.5' | 87° 28.7' | August 8 | 44° 5.0' | 86° 30.0' | 46 | 61 | Yes |
| 663 | 43° 40.5' | 87° 30.5' | ... | ... | ... | ... | ... | ... |
| 664 | 43° 41.6' | 87° 32.5' | August 7 | 43° 40.0' | 86° 32.0' | 45 | 53 | Yes |
| 665 | 43° 42.6' | 87° 34.7' | ... | ... | ... | ... | ... | ... |
| 666 | 43° 43.7' | 87° 36.9' | August 10 | 44° 27.0' | 86° 14.0' | 48 | 84 | Yes |
| Average | ... | ... | ... | ... | ... | [2] 29.7 | 37.6 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 26 | 27 | ... |

[1] With drags, 7; without drags, 20.
[2] Based on recoveries in year of release.

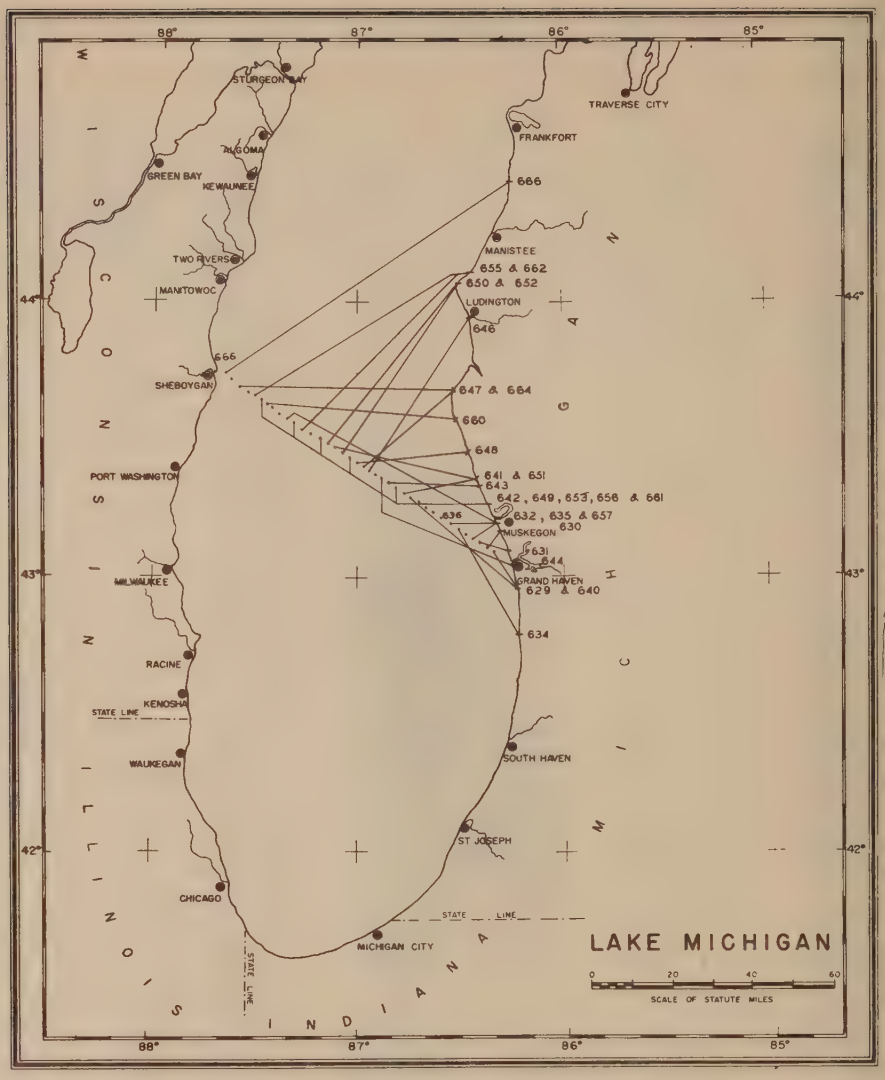



Figure 18.--Movements of bottles released along the transect, Grand Haven to Sheboygan, June 23, 1932.

TABLE 22. --Release and recovery points of drift bottles released June 24, 1932, at 33 stations between Sheboygan, Wisconsin, and Sturgeon Bay, Wisconsin

[Asterisk indicates recovery in years beyond 1932; no. 691 was recovered on June 6, 1942]

| Station of release | | | Recoveries | | | | | Drag attached [1] |
|---|---|---|---|---|---|---|---|---|
| Station number | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| 667 | 43° 45.5' | 87° 39.5' | August 5 | 44° 22.0' | 86° 16.0' | 42 | 80 | No |
| 668 | 43° 47.2' | 87° 38.5' | August 6 | 43° 22.0' | 86° 25.0' | 43 | 65 | No |
| 669 | 43° 48.7' | 87° 37.5' | ... | ... | ... | ... | ... | ... |
| 670 | 43° 50.6' | 87° 37.0' | August 5 | 43° 24.0' | 86° 26.0' | 42 | 64 | No |
| 671 | 43° 52.7' | 87° 36.2' | August 5 | 43° 57.0' | 86° 27.0' | 42 | 55 | No |
| 672 | 43° 54.4' | 87° 35.5' | ... | ... | ... | ... | ... | ... |
| 673 | 43° 56.1' | 87° 34.7' | August 4 | 43° 49.0' | 86° 26.0' | 41 | 56 | No |
| 674 | 43° 57.7' | 87° 34.0' | ... | ... | ... | ... | ... | ... |
| 675 | 43° 59.4' | 87° 33.3' | ... | ... | ... | ... | ... | ... |
| 676 | 44° 1.0' | 87° 32.6' | August 8 | 44° 7.0' | 86° 26.0' | 45 | 55 | Yes |
| 677 | 44° 2.8' | 87° 31.9' | August 6 | 44° 0.0' | 86° 29.0' | 43 | 50 | No |
| 678 | 44° 4.8' | 87° 31.4' | July 26 | 45° 0.0' | 86° 7.0' | 32 | 92 | No |
| 679 | 44° 6.6' | 87° 30.7' | August 4 | 44° 50.0' | 86° 4.0' | 41 | 86 | No |
| 680 | 44° 8.1' | 87° 30.0' | September 10 | 45° 3.0' | 86° 6.0' | 78 | 92 | Yes |
| 681 | 44° 10.2' | 87° 29.0' | August 19 | 44° 4.0' | 86° 31.0' | 56 | 48 | No |
| 682 | 44° 12.3' | 87° 28.4' | August 18 | 44° 7.0' | 86° 26.0' | 45 | 51 | Yes |
| 683 | 44° 14.2' | 87° 27.6' | July 30 | 44° 38.0' | 86° 15.0' | 36 | 64 | No |
| 684 | 44° 15.9' | 87° 26.8' | August 5 | 44° 37.0' | 86° 14.0' | 42 | 63 | No |
| 685 | 44° 17.6' | 87° 26.0' | September 18 | 45° 7.0' | 86° 4.0' | 86 | 87 | No |
| 686 | 44° 19.6' | 87° 25.4' | August 3 | 44° 40.0' | 86° 16.0' | 40 | 61 | No |
| 687 | 44° 21.3' | 87° 24.7' | July 29 | 44° 54.0' | 86° 2.0' | 35 | 78 | No |
| 688 | 44° 23.2' | 87° 24.0' | ... | ... | ... | ... | ... | ... |
| 689 | 44° 24.8' | 87° 23.2' | August 18 | 44° 56.0' | 85° 49.0' | 55 | 86 | No |
| 690 | 44° 26.6' | 87° 22.3' | July 28 | 45° 18.0' | 85° 22.0' | 34 | 114 | Yes |
| 691 | 44° 28.3' | 87° 21.6' | June 6* | 42° 28.0' | 82° 56.0' | 3,634 | 445 | No |
| 692 | 44° 30.2' | 87° 21.0' | ... | ... | ... | ... | ... | ... |
| 693 | 44° 32.0' | 87° 20.3' | ... | ... | ... | ... | ... | ... |
| 694 | 44° 33.8' | 87° 19.5' | July 23 | 45° 2.0' | 85° 46.0' | 29 | 84 | No |
| 695 | 44° 35.6' | 87° 18.8' | ... | ... | ... | ... | ... | ... |
| 696 | 44° 37.5' | 87° 18.1' | July 26 | 45° 3.0' | 86° 0.0' | 32 | 69 | No |
| 697 | 44° 39.9' | 87° 17.4' | August 7 | 44° 37.0' | 86° 14.0' | 44 | 52 | No |
| 698 | 44° 42.0' | 87° 17.8' | September 10 | 45° 3.0' | 86° 8.0' | 78 | 58 | No |
| 699 | 44° 44.4' | 87° 17.4' | August 17 | 44° 57.0' | 85° 23.0' | 54 | 110 | No |
| Average | ... | ... | ... | ... | ... | [2] 46.4 | [2] 71.7 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 24 | 24 | ... |

[1] With drags, 4; without drags, 21.
[2] Based on recoveries in year of release.

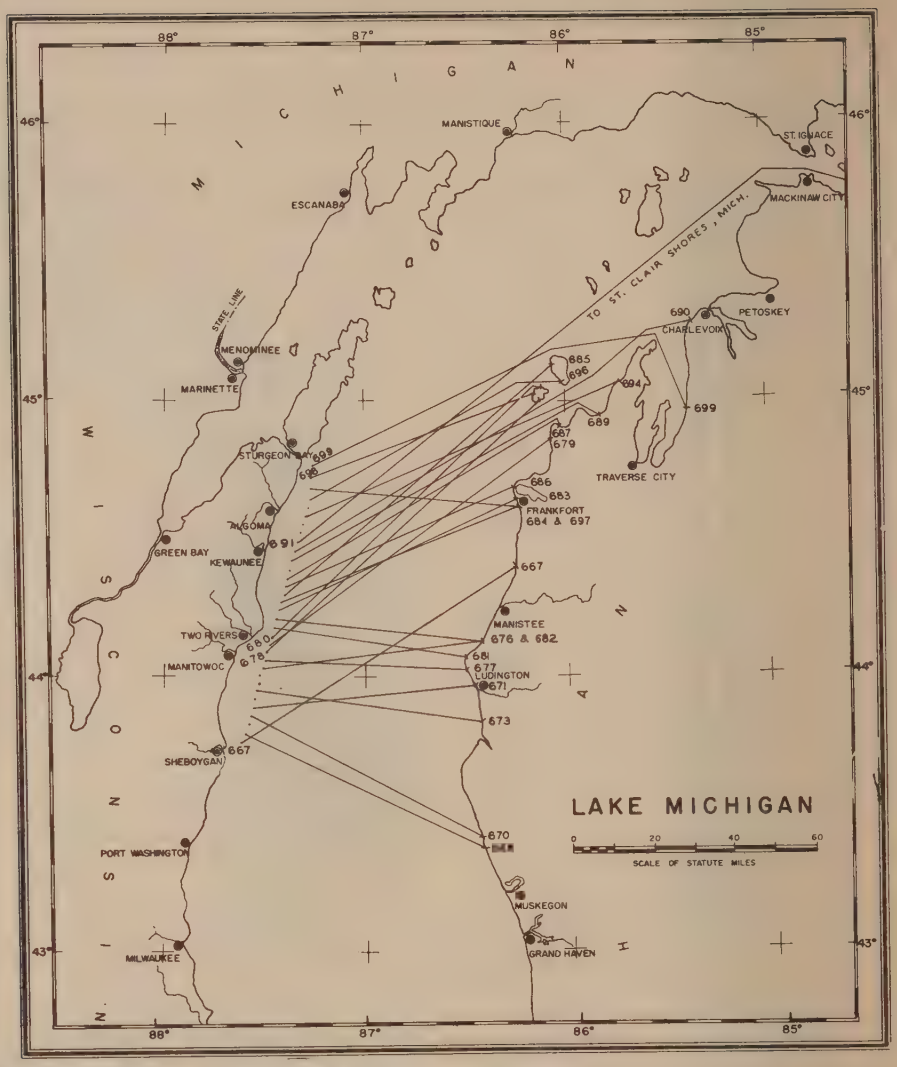



Figure 19.--Movements of bottles released from Sheboygan to Sturgeon Bay, June 24, 1932.

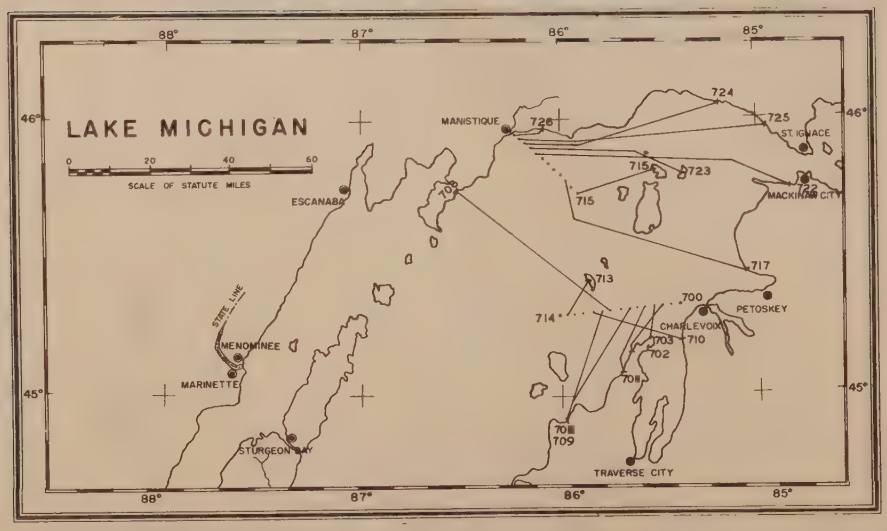



Figure 20.--Movements of bottles released from Charlevoix to Guiken's Reef, August 9, and from Gull Island to Manistique, August 20, 1932.

TABLE 23. --Release and recovery points of drift bottles released in 1932 from Charlevoix to Guiken's Reef (August 9--15 stations) and from Gull Island to Manistique, Michigan (August 20--12 stations)

[Asterisk indicates recovery in years beyond 1932; no. 703 was recovered on August 6, 1933, no. 708 on July 19, 1933, no. 722 on May 3, 1933, no. 713 on November 1, 1935, and no. 724 on June 29, 1933]

| Station of release | | | Recoveries | | | | | Drag attached [1] |
|---|---|---|---|---|---|---|---|---|
| Station number | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| August 9 | | | | | | | | |
| 700 | 45° 19.0' | 85° 22.8' | ... | ... | ... | ... | ... | ... |
| 701 | 45° 18.8' | 85° 25.2' | ... | ... | ... | ... | ... | ... |
| 702 | 45° 18.7' | 85° 28.0' | August 19 | 45° 8.0' | 85° 39.0' | 10 | 15 | Yes |
| 703 | 45° 18.5' | 85° 30.7' | August 6* | 45° 13.0' | 85° 33.0' | 362 | 8 | Yes |
| 704 | 45° 18.3' | 85° 33.2' | September 19 | 45° 3.0' | 85° 45.0' | 41 | 17 | Yes |
| 705 | 45° 18.1' | 85° 35.8' | ... | ... | ... | ... | ... | ... |
| 706 | 45° 18.0' | 85° 38.5' | August 19 | 44° 54.0' | 85° 58.0' | 10 | 32 | No |
| 707 | 45° 17.8' | 85° 41.1' | ... | ... | ... | ... | ... | ... |
| 708 | 45° 17.7' | 85° 44.0' | July 19* | 45° 45.0' | 86° 30.0' | 334 | 49 | No |
| 709 | 45° 17.6' | 85° 46.8' | August 27 | 44° 54.0' | 85° 58.0' | 18 | 29 | Yes |
| 710 | 45° 17.5' | 85° 49.5' | August 27 | 45° 11.0' | 85° 23.0' | 18 | 23 | No |
| 711 | 45° 17.3' | 85° 53.4' | ... | ... | ... | ... | ... | ... |
| 712 | 45° 17.1' | 85° 55.0' | ... | ... | ... | ... | ... | ... |
| 713 | 45° 16.8' | 85° 57.3' | August 28 | 45° 25.0' | 85° 52.0' | 19 | 10 | Yes |
| 714 | 45° 16.6' | 85° 59.8' | ... | ... | ... | ... | ... | ... |
| Average | ... | ... | ... | ... | ... | [2] 19.3 | 22.9 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 6 | 8 | ... |
| August 20 | | | | | | | | |
| 715 | 45° 42.6' | 85° 54.0' | September 4 | 45° 49.0' | 85° 31.0' | 15 | 19 | No |
| 716 | 45° 43.8' | 85° 55.7' | ... | ... | ... | ... | ... | ... |
| 717 | 45° 45.0' | 85° 57.3' | September 9 | 45° 28.0' | 85° 5.0' | 20 | 52 | No |
| 718 | 45° 46.3' | 85° 59.2' | ... | ... | ... | ... | ... | ... |
| 719 | 45° 47.5' | 86° 1.4' | ... | ... | ... | ... | ... | ... |
| 720 | 45° 48.8' | 86° 2.8' | ... | ... | ... | ... | ... | ... |
| 721 | 45° 50.0' | 86° 4.6' | ... | ... | ... | ... | ... | ... |
| 722 | 45° 51.1' | 86° 6.6' | May 3* | 45° 45.0' | 84° 49.0' | 256 | 64 | Yes |
| 723 | 45° 52.3' | 86° 8.4' | November 2* | 45° 47.0' | 85° 22.0' | 1,169 | 38 | No |
| 724 | 45° 53.6' | 86° 10.0' | June 29* | 46° 3.0' | 85° 11.0' | 313 | 49 | No |
| 725 | 45° 54.8' | 86° 11.7' | October 3 | 45° 57.0' | 84° 56.0' | 44 | 61 | No |
| 726 | 45° 56.1' | 86° 13.5' | September 15 | 45° 58.0' | 86° 4.0' | 26 | 7 | Yes |
| Average | ... | ... | ... | ... | ... | [2] 26.2 | 41.4 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 4 | 7 | ... |

[1] August 9--with drags, 5; without drags, 3. August 20--with drags, 2; without drags, 5.
[2] Based on recoveries in year of release.

TABLE 24. --Release and recovery points of drift bottles released in 1932 from Charlevoix, Michigan to Dahlia Shoal (August 23--13 stations) and northwest of Charlevoix (August 25--9 stations)

[ Asterisk indicates recovery in years beyond 1932; nos. 735 and 738 were recovered on April 16, 1933 no. 740 on April 22, 1933, and no. 743 on May 4, 1933 ]

| Station of release | | | Recoveries | | | | | Drag attached [1] |
|---|---|---|---|---|---|---|---|---|
| Station number | Latitude | Longitude | Date | Latitude | Longitude | Days after release | Minimum miles covered | |
| August 23 | | | | | | | | |
| 727 | 45° 22.6' | 85° 14.7' | August 31 | 45° 24.0' | 84° 55.0' | 8 | 16 | Yes |
| 728 | 45° 23.4' | 85° 14.0' | ... | ... | ... | ... | ... | ... |
| 729 | 45° 24.5' | 85° 13.7' | September 8 | 45° 42.0' | 84° 57.0' | 16 | 24 | Yes |
| 730 | 45° 25.4' | 85° 13.4' | ... | ... | ... | ... | ... | ... |
| 731 | 45° 26.3' | 85° 13.2' | ... | ... | ... | ... | ... | ... |
| 732 | 45° 27.2' | 85° 12.9' | August 28 | 45° 35.0' | 85° 7.0' | 5 | 10 | Yes |
| 733 | 45° 28.1' | 85° 12.5' | ... | ... | ... | ... | ... | ... |
| 734 | 45° 29.0' | 85° 11.9' | ... | ... | ... | ... | ... | ... |
| 735 | 45° 29.9' | 85° 11.5' | April 16* | 45° 46.0' | 85° 2.0' | 236 | 19 | No |
| 736 | 45° 30.8' | 85° 11.0' | August 30 | 45° 33.0' | 85° 7.0' | 7 | 4 | No |
| 737 | 45° 31.7' | 85° 10.7' | ... | ... | ... | ... | ... | ... |
| 738 | 45° 32.6' | 85° 10.3' | April 16* | 45° 46.0' | 85° 2.0' | 236 | 16 | No |
| 739 | 45° 33.5' | 85° 9.9' | ... | ... | ... | ... | ... | ... |
| Average | ... | ... | ... | ... | ... | [2] 9.0 | 14.8 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 4 | 6 | ... |
| August 25 | | | | | | | | |
| 740 | 45° 26.6' | 85° 27.2' | April 22* | 45° 37.0' | 85° 5.0' | 240 | 22 | Yes |
| 741 | 45° 26.6' | 85° 27.2' | September 23 | 45° 21.0' | 85° 15.0' | 29 | 12 | Yes |
| 742 | 45° 26.6' | 85° 27.2' | November 6 | 45° 22.0' | 85° 0.0' | 73 | 22 | No |
| 743 | 45° 26.6' | 85° 27.2' | May 4* | 45° 21.0' | 85° 15.0' | 252 | 12 | Yes |
| 744 | 45° 26.6' | 85° 27.2' | September 18 | 45° 21.0' | 85° 15.0' | 24 | 12 | No |
| 745 | 45° 26.6' | 85° 27.2' | ... | ... | ... | ... | ... | ... |
| 746 | 45° 26.6' | 85° 27.2' | ... | ... | ... | ... | ... | ... |
| Average | ... | ... | ... | ... | ... | [2] 42.0 | 16.0 | ... |
| Number of bottles | ... | ... | ... | ... | ... | 3 | 5 | ... |

[1] August 23--with drags, 3; without drags, 3. August 25--with drags, 3; without drags, 2.

[2] Based on recoveries in year of release.

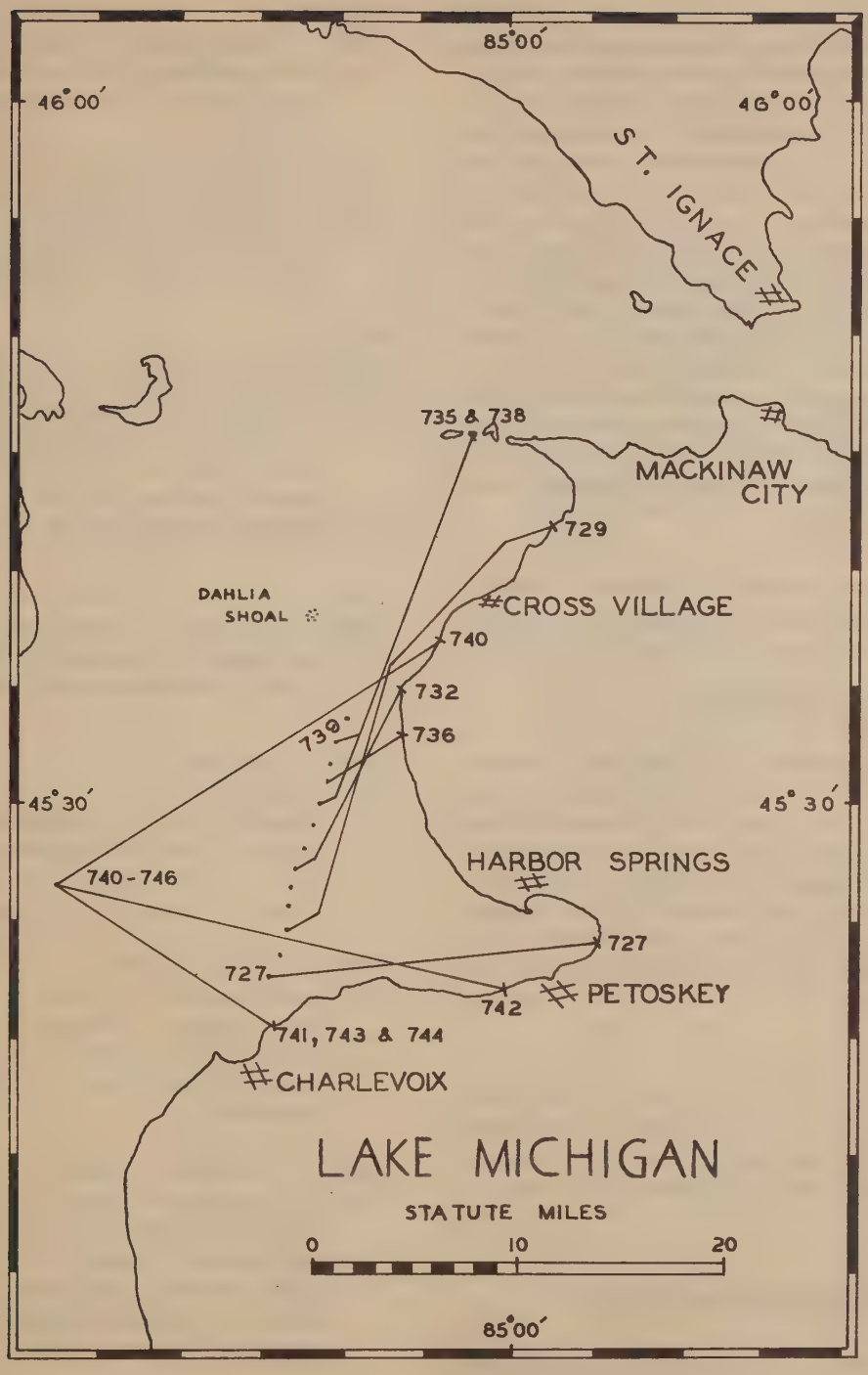



Figure 21.--Movements of bottles released from Charlevoix to Dahlia Shoal, August 23, and northwest of Charlevoix, August 25, 1932.

In 1932, the transect bottles were deposited only from Grand Haven to Sheboygan, from Two Rivers to Frankfort, and from Charlevoix to Manistique; all others were dropped along the shores. Of the 119 recoveries of transect bottles, 103 or 86.6 percent were found on the eastern shore and only 16 or 13.4 percent along the western coast. Of the other 212 bottles recovered, 173 or 81.6 percent were discovered along the eastern shore and 39 or 18.4 percent along the western coast (38 of which were found in Green Bay). It is unusual to find that all 25 recovered bottles deposited from Sheboygan to Sturgeon Bay floated to the eastern shore. Of the entire total of recovered bottles, 276 (83.4 percent) were taken along the eastern shore and 55 (16.6 percent) along the western coast.

Most of the bottles had drifted northeast in 1931 and northeast and southeast in 1932.

## SUMMARY

The U.S. Bureau of Fisheries conducted studies of movements of drift bottles in Lake Michigan in 1931 and 1932. Releases totaled 283 in 1931, 462 in 1932, and 745 in both years. Dates of releases were June 17 to August 17, 1931, and May 9 to August 25, 1932. Returns amounted to 186 cards or 65.7 percent of the 1931 releases, 331 or 71.6 percent of the 1932 releases, and 517 or 69.4 percent for the 2 years.

Most of the recovered bottles dropped along transects moved to the eastern shore. About 68 percent of the bottles deposited along the western shore had also floated to the eastern coast.

## LITERATURE CITED

AYERS, JOHN C., DAVID C. CHANDLER, GEORGE H. LAUFF, CHARLES F. POWERS, and E. BENNETTE HENSON.
1958. Currents and water masses of Lake Michigan. Great Lakes Research Institute, University of Michigan, Publication No. 3, 169 p.

BARNARD, H. E., and J. H. BREWSTER.
1909. The character of the water supply of Michigan City, Indiana. First Report of Lake Michigan Water Commission, p. 135-189.

1909b. The sanitary condition of the southern end of Lake Michigan, bordering Lake County, Indiana. First Report Lake Michigan Water Commission, p. 191-266.

CROHURST, H. R., and M. V. VELDEE.
1927. Report of an investigation of the pollution of Lake Michigan in the vicinity of South Chicago and the Calumet and Indiana harbors 1924-1925. U.S. Public Health Bulletin No. 170, vii +134 p.

DEASON, HILARY J.
1932. A study of surface currents in Lake Michigan. The Fisherman, vol. 1, no. 5, p. 3-4, 12. Grand Haven, Michigan.

HARRINGTON, MARK W.
1894 Currents of the Great Lakes, as deduced from the movements of bottle papers during the seasons of 1892 and 1893. U.S. Department of Agriculture, Weather Bureau Bulletin B.

1895. Surface currents of the Great Lakes, as deduced from the movements of bottle papers during the seasons of 1892, 1893, and 1894. 2d ed. U.S. Department of Agriculture, Weather Bureau Bulletin B, 14 p.

HORTON, ROBERT E., and C. E. GRUNSKY.
1927. Hydrology of the Great Lakes. Report of the Engineering Board of Review of the Sanitary District of Chicago on the lake lowering controversy and a program of remedial measures, part III, appendix II, xvii + 432 p.

JOHNSON, JAMES H.
1960. Surface currents in Lake Michigan 1954 and 1955. U.S. Fish and Wildlife Service, Special Scientific Report-Fisheries No. 338, viii + 120 p.

JUDSON, W. V.
1909. Currents in Lake Michigan. First Report Lake Michigan Water Commission, p. 63-68.

LAUFF, GEORGE H.
1957. Some aspects of the physical limnology of Grand Traverse Bay. Great Lakes Research Institute, University of Michigan, Publication No. 2, 56 p.

McLAUGHLIN, ALLAN J.
1912. Sewage pollution of interstate and international waters with special reference to the spread of typhoid fever. Hygienic Laboratory, Bulletin No. 83, 296 p.

RUSSELL, ISRAEL C.
1895. Lakes of North America. Ginn and Co., New York, 125 p.

SHELFORD, VICTOR E.
1918. Conditions of existence. Chapter 2, p. 21-60. *In* Henry Baldwin Ward and George Chandler Whipple, Fresh-water biology. John Wiley and Sons, Inc., New York.

SMITH, STANFORD H.
1956. Great Lakes fishery investigations. Research vessel "*Cisco*" operations in 1955. U.S. Fish and Wildlife Service, Commercial Fisheries Review, vol. 18, no. 5, p. 21-23.

1957. Limnological surveys of the Great Lakes--early and recent. Transactions American Fisheries Society for the year 1956, vol. 86, p. 409-418.

TOWNSEND, C. McD.
1916. The currents of Lake Michigan and their influence on the climate of the neighboring states. Journal Western Society Engineers, vol. 21, no. 4, p. 293-309.

WARD, HENRY B.
1896. A biological examination of Lake Michigan in the Traverse Bay region. Bulletin of the Michigan Fish Commission No. 6, p. 1-71.

MS #1160

GPO 927444

Created in 1849, the Department of the Interior—America's Department of Natural Resources—is concerned with the management, conservation, and development of the Nation's water, fish, wildlife, mineral, forest, and park and recreational resources. It also has major responsibilities for Indian and Territorial affairs.

As the Nation's principal conservation agency, the Department works to assure that nonrenewable resources are developed and used wisely, that park and recreational resources are conserved for the future, and that renewable resources make their full contribution to the progress, prosperity, and security of the United States—now and in the future.